SCIENTIFIC AMERICAN MONTHLY

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FLOWER-LIKE FAUNA OF THE SEA—A CASE AT THE AMERICAN MUSEUM OF NATURAL HISTORY INGENIOUSLY DESIGNED TO REPRESENT TWO INCHES OF SEA BOTTOM AS VIEWED THROUGH A MAGNIFYING GLASS (SEE PAGE 129)

SCIENTIFIC AMERICAN MONTHLY

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THE FAR FLUNG LINE

ONE of the most gratifying signs that the world is really settling itself into normal conditions in spite of the reverberations of the great conflict which still assail our ears, is to be found in the resumption of scientific exploration. The far flung line of savants whose fight is to gain knowledge extends through every country on the globe and embraces men of learning from all the centers of civilization. These men are single-minded in the pursuit of knowledge—they have no thought to exploit the native tribes whom they encounter, but merely to study their ethnical character, their habits and their traditions. Gold and diamonds interest them less than geological structure. The lion and elephant are hunted by them not for ivory or pelt, but that they may examine and describe them.

We take pride in the fact that American men of science are conspicuously active along such lines, and because of the liberality and far-sighted enterprise of the great institutions which support their efforts.

Under the auspices of the American Museum of Natural History, Mr. Roy C. Andrews has already established a base of operations in China for his great enterprise of extended research, particularly along anthropological and paleontological lines in the heart of Asia. The entire work is expected to require some five years, and the work of the first year of preliminary organization and preparation is already well under way with the coöperation of the Chinese Geological Survey.

Mr. Carl E. Akely, the distinguished African explorer and animal sculptor, will represent the same admirable institution in his expedition to the Lake region of Central Africa for which he departs sometime during the present month with the express purpose of making a study of the living gorilla in its native haunts. In an article in the present number a résumé is given of our present knowledge of this great man-like ape, which is the closest relative of man among the simians. Undoubtedly we may expect to have our knowledge greatly enlarged as a result of Mr. Akely's observations.

Mr. C. Wm. Beebe of the New York Zoological Park has recently returned from a fruitful and extended visit to British Guiana, where he made a special study of bird life. In an article in this issue on Four-Legged Birds, a delightful passage from a recent book by Dr. Beebe is quoted.

The picturesque Island of Trinidad was visited this spring by a party headed by Dr. Britton of the New York Botanical Gardens and much valuable material was obtained, which is now being studied and classified.

Dr. Rusby of the New York College of Pharmacy is now in Bolivia and expects to make an extended stay in South America searching for and studying medicinal plants.

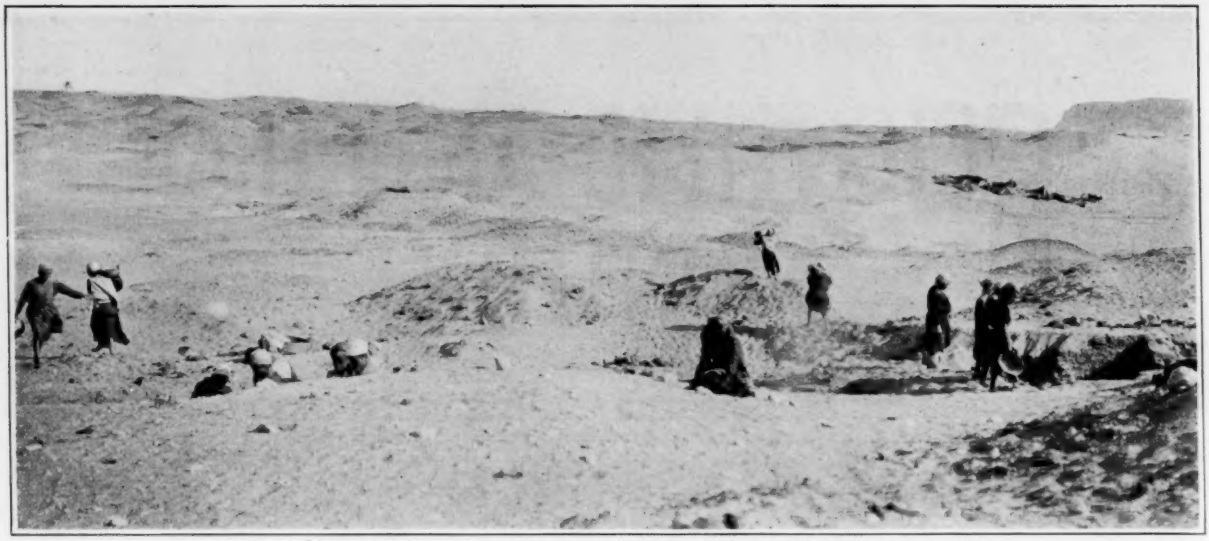
Thus we may rejoice that once more the sword and buckler of Mars have been dropped for the aegis of Minerva.

RADIANT ENERGY

DURING the past three or four years many and illustrious have been the visitors who have reached our hospitable shores. Princes and potentates, statesmen and diplomats, famous men of science, and noble women devoted to the cause of humanity have come to seek our aid and to lay the tribute of their heart-felt gratitude at our feet. But among the great of the earth who have thus honored us and been honored by us, none to our mind is more significant than the frail and gentle woman whose genius and patience, together with those of her husband, the late Pierre Curie, gave to the world a new element, so unique in character, and of so mysterious a potency that even now we do but glimpse the revelations to which it is the magic key.

Mme. Curie reached New York City in May for the express purpose of receiving in person the gift of one gram of radium presented to her by the women of America to enable her to continue her valuable researches upon radioactivity, both from a purely scientific point of view and with reference to its therapeutic powers.

It is not too much to say, perhaps, that in future eras this 20th century of ours may be known as the Age of the Discovery of Radium. And the torch lit by the labors of this unassuming but gifted woman has already lent its flame to many another wayfarer along the paths of scientific research. Mme. Curie has had enthusiastic disciples not only in France but in England, America, Germany, Italy and Switzerland. This magazine has given an account from time to time of the work done by Rutherford, Soddy, Perrin and others in the prolific field of the nature and potentialities of radioactive energy. We should like to call especial attention to an article by Professor Perrin in the present number. He has studied with avidity the work done along these lines by his predecessors and contemporaries, tested their theories by his own observations with regard to fluorescence, and arrived by a brilliant process of ratiocination at the startling theory that the atom, so far from liberating energy upon its disintegration, actually absorbs it. And as a corollary to this he boldly suggests that the phenomena observed may be due to radiations of shorter wave length than any which we have thus far been able to demonstrate and describe. He suggests further that the source of these rays, which he ingeniously terms the ultra-X-rays, may be the "ardent center of our earth itself," finding a logical justification of his theory in various facts observed by himself and other investigators in the realm of physics and chemistry. We must leave our readers to judge whether or not he has proved his point, but we can promise them a half hour of keen enjoyment, since, unlike too many men of vast scientific attainment, this brilliant Swiss scientist possesses the art of setting forth even highly abstruse ideas with fascinating lucidity and charm.



GENERAL VIEW OF THE SITE OF TELL EL-AMARNA, WHICH IS BEING EXCAVATED

Excavations at Tell El-Amarna

The Pacifist Pharaoh and the Beautiful Capital He Built on the Nile

Photographs by courtesy of the Egypt Exploration Society

THE Egypt Exploration Society of England and the United States, now in its thirty-ninth year, has taken up the task of the excavation of the capital of the "Heretic King" Amenophis IV, later named Akhnaton. The systematic excavation of the entire city, section by section, will require a number of years, but the recovery of Amarna as a whole is eminently worth while. The site is of dramatic interest.

Tell El-Amarna, 160 miles south of Cairo on the eastern bank of the Nile, is marked by a vast amphitheater of low, sandy hills worn by water-courses, by a narrow strip of cultivation along the river, by heaps of bricks, fragments of stone, broken walls running in every direction, and finally by one long street among the ruins cleared by the *Deutsche Orient-Gesellschaft*. The city was built on a regular plan, having many cross streets and at least two long main streets of handsome buildings with fine sculptures, and gardens filled with trees and plants of every kind. It was divided into two separate quarters by a valley, now packed with sand and gravel. Here excavation is slow on account of solid debris between house-walls due to alluviation and rubbish from upper buildings. An inscription in the tomb-chapel of May, a noble of the court praises "Akhetaten, the Mighty City of the Horizon of Aton, great in loveliness, mistress of pleasant ceremonies, rich in possessions, the offering of the sun being in the midst: at the sight of her beauty there is rejoicing."

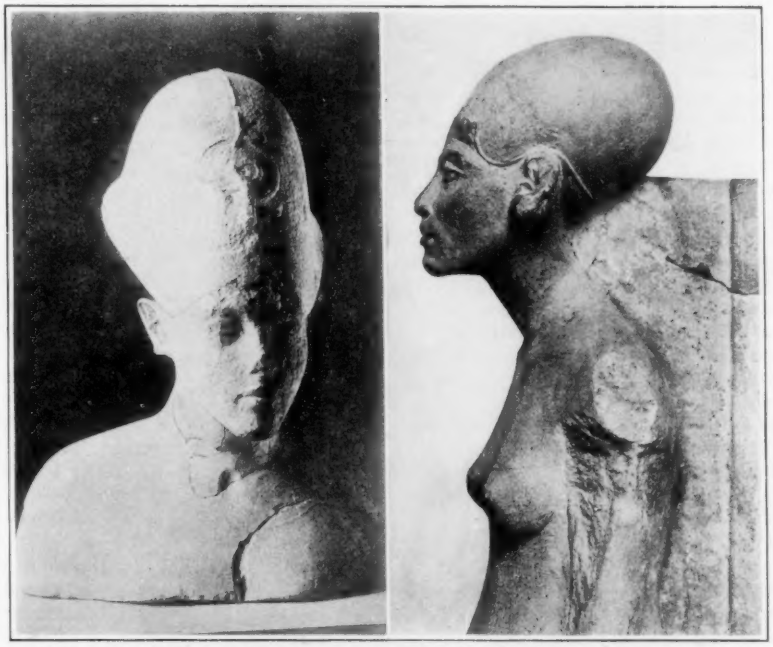
The history and remains of the place are equally singular. From a mere dependency of Hermopolis with no life of its own, it became the seat of imperial administration, for Akhnaton, Pharaoh from 1375 to 1358 B.C., repudiated the Amen-Priesthood, abandoned Thebes, and founded here his glorious new capital "Like Aton in heaven forever and ever." Aton was the "Lord of Peace" who could not tolerate battle and strife. Akhnaton was so opposed to war that he persistently refused to offer armed resistance to the subsequent revolts in his Asiatic dominions. The Egyptian government became chaotic. An empire gained by 200 years of conquest was scattered and lost in less than twenty years; and with its fall the king died. Upon the death of Akhnaton the religious revolution ended. The court returned to Thebes and the wonder city of Pharaoh's dream was once more a desolate place. Dr. Hogarth writes: "Its greatness had lasted but a moment, and everything important found on the site was made, or at least brought there during that moment. Its period is one of exceptional interest to historians and archaeologists, falling as it does just after the zenith of the imperial eighteenth dynasty, which extended Egyptian dominion more widely over the Near East than any before or after. It was a time of much splendor and great art, to whose inspiration influences of practically all the lands then civilized contributed. Relations with other Mediterranean peoples—for example, the Cretans in their "late Minoan" age—and with Western Asia from Mesopotamia to Asia Minor, were frequent and close. Egypt was for the moment the leading state in the world. Not only the Kings of Knossos, but of Hittite Cappadocia, of Assyria, of the Mitannian State in northern Mesopotamia, and of the Kassite dynasty in Babylonia, courted it and were wary of provoking its wrath. The evidence of these wide relations which the soil of Amarna has yielded up already is the most interesting that, perhaps, has come from any ancient site."

In 1887 the attention of scientists was first directed to the forgotten capital. Natives, pulling down a portion of the palace wall for building material, came upon a store-room filled with bricks of very fine grain, each covered with cuneiform writing. The tablets were hastily heaped in baskets, fastened to the backs of donkeys, and a few days later the dealers in Luxsor and Cairo had on sale the diplomatic correspondence of Amenophis III and Amenophis IV (Akhnaton) with the Babylonian and Syrian dynasts. This find of documents of absorbing historical interest led Professor Petrie to commence excavation of the actual buildings. In 1891 he cleared a group of town houses, finding more cuneiform tablets, the great temple and the king's palace. Like all the residential buildings of the period the palace was an airy and light structure made of brick. The walls, ceilings and floors were covered with beautiful paintings; pillars inlaid with colored glass and stones supported the light roof. A. E. P. Weigall, Inspector of Antiquities in Upper Egypt describes a portion of the designs

painted on the palace pavement: "A young calf frisking in the sunlight, gallops through a field of red poppies; wild geese rise from the marshes and beat their way through reeds disturbing the butterflies: amidst the lotus blossoms resting upon the rippling water the sinuous fish are seen represented in the ponds. These are but fragments of the paintings which once delighted the eyes of Pharaoh." These paintings, among the most valuable monuments in the realistic art of the eighteenth dynasty, were wantonly destroyed by a discharged workman in 1912 who broke into the government shed and reduced the entire pavement to broken fragments and heaps of colored dust. Such misfortune emphasizes the need for excavation and scientific record of a site remote and difficult for the government to protect.

THE LANDING AT EL-AMARNA

From 1907 the *Deutsche Orient-Gesellschaft* held the site and in 1911 commenced clearance of the city building by building. The German work ended in 1914 with the clearance of the long *Oberpriester - Strasse* which developed into an Egyptian Pompeii of noble villas. Nowhere else in Egypt is there such an opportunity for studying the dwellings of the ancients. Dr. James H. Breasted writes for this article on account of his visit to Tell El-Amarna: "In the light of many years of study devoted to its monuments, and especially in view of an unusually interesting visit to the place which I made only last season, it is a great pleasure to express my conviction of the value of excavations and researches carried on at this remarkable site. To the average traveler the place seems to offer very little of interest; indeed, the tourist steamers on the Nile almost never stop there. On disembarking, the modern traveler rides through the palm groves, and issuing from the cultivation enters what seems to be only a wilderness of the dreariest mounds of disintegrated sun-dried brick extending for miles across the desert; but where these mounds now stretch away under the blazing Egyptian sunshine once arose a beautiful city, the earliest home of monotheism. The Pharaoh Ikhnaton (Akhnaton), to whom the place owed its origin, was a religious and artistic genius, born like most such extraordinary personalities many centuries too soon. His people and his time could not follow him or appreciate the value of his extraordinary vision, and his whole movement toward the worship of a sole God and toward purer truth and realism in art was swept away.



AKHNATON, PHARAOH FROM 1375-1358 B. C.

QUEEN NEFERTITI AFTER CHIEF SCULPTOR THUTMOSE

"Today as you walk across the desolate ruins you may trace the streets of the town and the walls of the houses, rising sometimes almost to the level of the ceiling of the ground floor rooms, and displaying here and there the bright colors of the paintings with which they were once adorned. Here was the king's palace. Here were the temples of the sole God. Grouped about these were the villas and the gardens of the powerful leaders whom the revolutionary Pharaoh had been able to rally to his cause. The investigation of these remains is only in its beginnings.

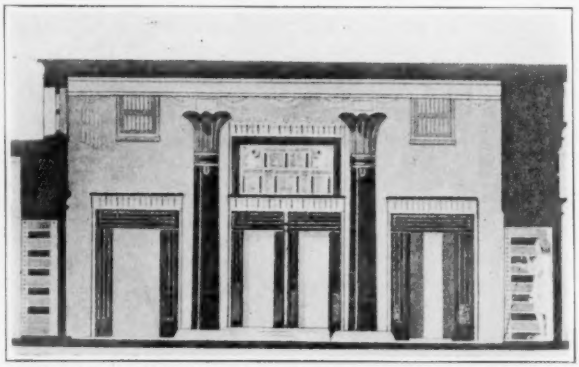
"When I visited the place last season, even the limited extent of the initial excavations already revealed a scene of fascinating interest. I wandered from house to house, passing through the porter's lodge, and sometimes a small vestibule. Behind these one usually found a stately transverse reception or social hall with a raised section of floor at one end fitted with drainage and evidently intended for the wine jars, thickly hung with flowers and garlands, and constantly sprinkled with water, just as we so often see them in the paintings of Egyptian feasts in the towns at Thebes. Behind all this were sleeping rooms, sometimes with a bath, and with hygienically arranged toilet conveniences. Connected with the kitchen might be circular granaries, store-houses and magazines, while behind all was the garden with the stumps of the vanished trees still in posi-

tion, and the well from which the garden was watered still accessible by means of a spiral stairway leading down to the water. The treasures which such houses may still contain have been surprisingly demonstrated by the marvelous sculptures discovered in the course of the German excavations—especially the treasures of portraiture found in the house of the royal sculptor Thutmose, with the studio of the royal sculptor himself attached to his dwelling, and adjoining it a large court surrounded by the booths and alcoves in which his pupils and apprentices carried on their work and their studies.

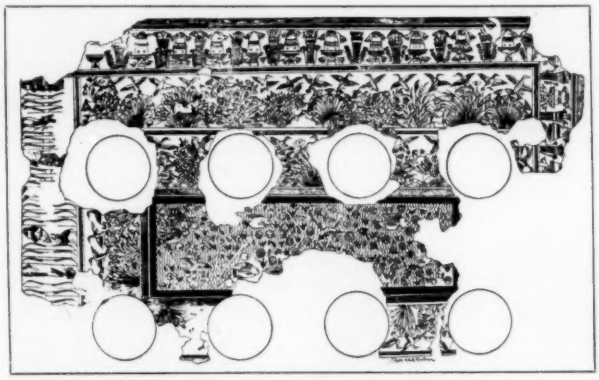
"Never in the whole course of its work in Egypt has the Egypt Exploration Society taken up a site of such extraordinary interest and of such great promise. The work ought to receive wide support from American subscribers, and the fact that the antiquities taken out by the Society are divided pro-rata among the contributing communities in America and Europe offers every possible inducement to Americans who are interested in such work."

An account of the discoveries of the past winter received at Tremont Temple, the American headquarters of the Egypt Exploration Society is surprising and important in scientific results.

Professor T. Eric Peet, Director of the Expedition, sends the account by way of London. The section excavated adjoins the "Oberpriester-Strasse" and was supposed by the Germans to be a cemetery. It proved an ancient village, the dwelling place of the necropolis guards. The village was surrounded by a thick wall having a rather narrow door as entrance to the enclosure. Almost the first stroke of the pick showed that the white ants which had so ravaged wood work in the villas of "Street of the High Priest" had barely touched this area. Rafters and roofing, though fallen in, were preserved almost intact, enabling us to make an advance on the German work in the way of reconstruction. The typical house stands in a spacious enclosure. It is built of mud-brick, and its rooms are roofed with mud and reeds, supported where necessary by columns of wood set on stone bases. In the center of the house was the central hall, whose walls standing higher than those of the surrounding rooms enabled the room to be lighted by a kind of clerestory. In this hall is always found a flat stone tank, draining off into a vase of pottery or stone. Opening into the central hall are two long rooms on the north and west, each of which seems to have had a broad low window in its outer wall which turned the room into a half open loggia. East or south of the central hall is usually a staircase, half of brick and half of wood leading up to the roof. Other apartments include women's quarters and men's quarters, and a bath room containing a stone bath similar to but not to be confused with the tank in the central hall. In the store-rooms remains of the wine and oil jars are still to be found, often marked in ink with the name and quality of their contents.



THE "DEEP HALL" IN THE HOUSE OF GENERAL RA'-MOSE
After a provisionally colored reconstruction. Scale, 1:55



THE DECORATED PAVEMENT OF THE PALACE OF AKHNATON, WHICH WAS DESTROYED IN 1912

SECTION OF PAINTING FROM THE PALACE PAVEMENT

One householder certainly had things more valuable to conceal for he had built a small bricked pit under the brick floor of his central hall. At the time when the town came to be deserted he had taken up the bricks of his floor, broken up the securely plastered stone lid of the pit and removed his treasure, evidently in considerable haste, for he dropped a scarab of lapis lazuli with gold setting on the floor beside the pit. One kitchen was found in perfect order, with oven, tray for baking bread, basket for cooling, vase for water, dough-mixing place, fireplace with poker, unused fuel and the cooking pot. Similarly two rooms have looms in them of which considerable portions remain. Very interesting museum material of a type which is rare was found. Among the implements of labor are sieves, basket-work, wooden tools, portions of looms, spindle whorls, ropes, etc.

The garden contains a great wall, granaries, stables, a cooking place with pottery ovens, a summer-house, and remains of trees. Everywhere are traces of the gaiety and brightness which seem to have characterized the worship of the Sun's Disk and its devotees. Every day brought to light fragments of charming blue-glaze finger-rings, amulets and daintily colored tiles. From the town came several interesting small works of art, sculptor's trial pieces, fine perfect vases of the beautiful variegated glass of the XVIIIth Dynasty and two silver bowls; Mycenean pottery, and a tablet written in Assyrian.

The dated objects are so far of Tutankhamon, which becomes of special interest in connection with the discovery of a series of shrines. On the hill-slope east of the village re-

mains of an entirely new type came quickly to light. A small chamber, perhaps roofed only in part or not at all, ends in a raised dais, behind which is a cavetto cornice only about a foot from the pavement of the niche. The whole structure was whitewashed up to a certain height, and above this were decorations of painted plaster. In the center niche is a small brick pedestal, which presumably held a cult object. A find in another shrine may bear on this. Side by side at the foot of the dais were found an inscribed wooden pedestal, and a wooden disk of the sun which had undoubtedly been mounted on this pedestal by means of a dowel and two pegs. In one of the shrines were two steles. One is a fine funerary stele of Ptaymay who is called "The Approved of Aton." On the front is a scene showing Shed and Isis and prayers to these. A neighboring shrine has prayers to Amon. A small stele of Taurt from the town site and amulets of Bes also mark the intrusion of the old gods and indicate readiness to break with the cult of Aton. These point to the reign of Tutankhamon, who changed his name from Tutankhaten after the death of Akhnaton; four of his scarabs are known reading Tutankhamon, but having the gold-disk of the Aton inserted in the back, a concession to worship of the Sun-Disk in former days.

In connection with the shrines found by Professor Petrie, hope of discovery of the royal shrines is renewed. Weigall, when Inspector of Antiquities, wrote: "It would seem that there were shrines dedicated to Akhnaton's ancestors in the City of the Horizon, each of which had its steward and its officers, and it is probable that Akhnaton arranged that a memorial shrine of the same kind should be erected for himself against his death, for we read in the "Rock-Tombs of El-Amarna" of a personage who was "second-Priest" of the king. There is also a representation of Akhnaton offering to Aton in the House of Thotmes IV (his grandfather) in the City of the Horizon. It was Akhnaton's desire to show in this manner the continuity of his descent from the Pharaohs of old and to demonstrate his real claim to the title "Son of the Sun," which had been held by the sovereign of Egypt ever since the Vth Dynasty. It was in this manner that he claimed descent from Ra, who was to him the same with Aton. Even as the great religious teachers of the Hebrews made careful note of their genealogies in order to prove themselves descended from Adam and hence in a measure from God, so Akhnaton thus demonstrated the continuity of his line in order to show his real right to the titles "Child of Aton" and "Son of the Sun."

THE GRASPING INSTINCTS OF YOUNG ANIMALS IN THE LIGHT OF EVOLUTION

IN newly-born mammals there is frequently found a remarkable grasping instinct. Everyone has noticed this in young babies, who exhibit a really marvelous power of "holding fast" to a finger or a stick. Writing in *Kosmos* (Stuttgart) for April, 1921, Mr. H. Radestock points out that this represents the survival of a highly useful atavistic power. This faculty is confined chiefly to those animals, including man and great apes, which are known as breast nurslings, and in a somewhat less degree to the pouch nurslings, which include kangaroos and marsupial rats. This is because the instinct referred to is not especially useful to those animals which nurse their young in a recumbent position such as dogs, cats, rabbits, etc., or to those where the infant is able to take its food standing—like calves, colts, fawns, young elephants, etc.

In some recent investigations upon this subject the well-known naturalist, Professor Doflein, divides the first-mentioned mammals into two classes, those in which the new-born offspring cling to the fur of the mother by means of hook-like incisors, as do all the bats, and those which cling to the mother's breast with the hands and feet, like the young of the man-like apes and of man himself. It has long been a matter of remark, in fact, that among certain African tribes the mothers carry their young infants while walking or while working in a manner quite similar to that employed by the great apes. It is true that they add to the security of the child by a primitive method of fastening it to the body, but it is quite noticeable that the little creature clings to its mother's torso by means of its arms and feet with a really wonderful degree of firmness and endurance. Apropos of this we may mention Professor Mitchell's well-known experiments with regard to the grasping power of young infants. Most of them are capable of hanging suspended from a rod when gripping it with both hands for a considerable length of time, while a few young Hercules are capable of hanging by one hand. And since at the same time they make instinctive motions with their legs, they look uncommonly like young gymnasts.

It has hitherto been quite a puzzle as to why children so quickly lose this power. The answer to the riddle is given through a very simple experiment described by Dr. E. Moro in the Munich *Medical Weekly*. If a young infant be laid upon a mattress and the latter then be slapped smartly with both hands one on each side of the child the latter's arms and legs will at once fly apart in symmetrical curves and immediately afterward, approach each other with an energetic contraction. This is an automatic grasping movement produced by fright; its object being naturally the clasping and clinging to of the mother's body. It must be regarded, therefore, as a primordial flight reflex, an instinctive measure of protection, which in the prehistoric days of our race enabled the mother at once to take flight with her baby hanging on tight to her body, and thus not impeding her through the necessity of carrying it in her arms. After the infant is weaned this instinct is no longer necessary and consequently becomes atrophied. Observation has shown that the convulsive contraction of the arms and legs in young children persists more than three months. This similarity between the instincts in young children and in the offspring of the higher apes is another proof that both these families of primates sprang originally from a common stock.

GENERATORS FOR WIRELESS TELEGRAPHY

KARL SCHMIDT, a German radio engineer, reviews in this paper some German developments in the radio field during the war. Designers of medium-frequency and high-frequency generators will find in his paper details, drawings and photographs never before published. The largest part of the paper deals with different types of generators used for the operation of quenched-spark sending stations, *i.e.*, machines producing up to 600 cycles per second. The author describes several solid-steel rotor, unipolar machines and gives their characteristics. There has been a large demand for medium-frequency machines of from 0.05 kw. up to 300 kw. output, which has resulted in highly developed standard types. During the war a large number of these machines, rated at about 350 watts, 600 cycles, and simultaneously at 200 watts, 500 volts direct current, operating at 4,500 r.p.m. and weighing only about 17 pounds, have been used on airplanes.

Considerable attention is given a new type of generator developed by the author during the war which found widest use in the German army and navy. It is a type with all windings stationary and a laminated toothed rotor. The author claims for his machine the smallest weight and highest efficiency ever reached for such generators; for example, 11 lb. for 500-watt alternating current plus 250-watt direct-current type, or 82 per cent efficiency for a 2-kw. type. A very compact, portable, gasoline-driven 1.5-kw. alternating-current plus 1.0-kw. direct-current type is also described.

Dealing with high-frequency machines the author does not consider it as reliable to go beyond 3,000 r.p.m. or 450 ft. peripheral speed per second. The multiplying of frequency in stationary transformers according to Jolly-Arco and Goldschmidt is touched upon, assuming eightfold and threefold, respectively, as safe limits. Characteristic curves are given of a 7,000-cycle machine in actual operation.—*Elektrotechnische Zeitschrift*, March 17 and 24, 1920. Also *Electrical World*, June 11, 1921.

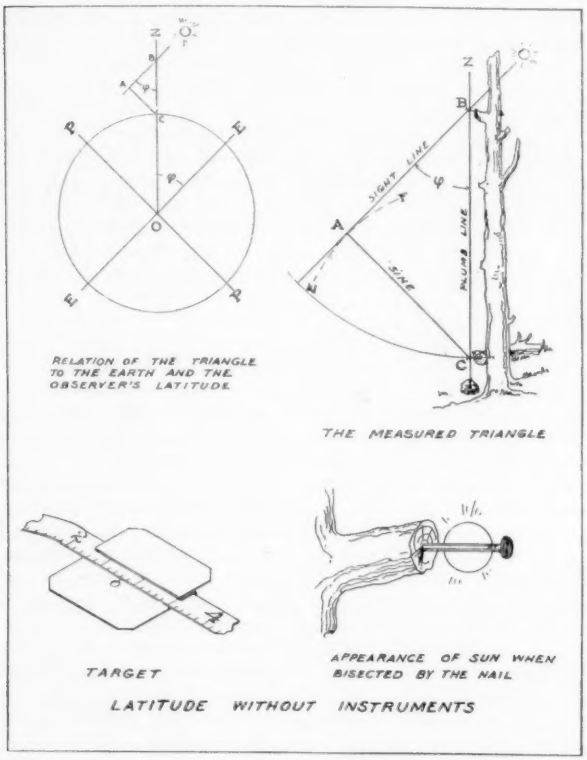
Latitude Without Instruments*

How the Man in the Woods Can Make an Excellent Determination

By Russell W. Porter

"NOT within a mile of the truth" usually means that something or other lies very far from the mark. Locating ourselves within a mile of the truth on this immense globe of ours would, however, be considered a pretty close approximation. To do it with only a string, this approximation would seem to be a remarkably close one.

Two winters ago a good friend—William Brooks Cabot of Boston—well known for his exploratory work in Labrador, suggested that latitude could be determined in the field without an instrument of precision. He deplored even the addition of a pocket sextant and horizon to a camper's pack where dead weights must be shaved to a minimum; that the tools irreducible to the explorer—a knife, hatchet and fishline—together with nature's available materials, would suffice to obtain latitude within a mile. He had not put the theory into practice, however.



And the writer, doubting that any such accuracy could be reached, put the method to the test. He was greatly surprised, after several false starts, and hitting luckily at last on a novel expedient, to find that latitude could be obtained with a steel tape to well within a statute mile; time (and hence longitude) correspondingly.

The problem resolves itself into the measurement of a vertical angle. In Todd's "New Astronomy," page 82, is described a simple way of finding one's latitude. It obtains the zenith distance by allowing a beam of sunlight to fall on a graduated arc oriented in the observer's meridian. It will probably give one's latitude to the nearest degree.

If now we take the simple case of the sun on the equator at noon, and suspend a weighted line BC from any convenient support, and from its lower end stretch another line AC to our eye when it sees the sun and the point B in line, we have formed a right angle triangle in which the angle ABC will be our latitude. This statement is made clear in the smaller diagram, where an observer at A finds that the angle between his zenith and the equator (in this case a very distant object lying in the plane of our equator) will always be his latitude.

Now in this triangle ABC the hypothenuse BC is readily and accurately determined. The plumb line may be suspended from the limb of a tree or from a nail driven into the top of a porch post, or on the corner of a house. A good working length is about ten feet. Since the angle we desire is angle ABC, if we can measure the side AC then the sine of this angle is at once found and the angle may be taken directly from a table of sines.

It now remains to work out a convenient means of measuring this sine, and the writer has found that the following procedure gives the most satisfactory results. While a fishline or cord can be used, since the ratio only of AC to BC is required, yet more accuracy is attained with a small pocket steel tape whose feet are divided into tenths and these again into tenths. As these last divisions may be estimated to tenths, we obtain readings to one thousandth of a foot.

The point C at the lower end of our plumb line is next fixed in a secure manner.

I have found it practical to bring the end of a sapling or small log up to the base of the tree when in the wilds, and to drive a nail into the butt opposite to some whole division on the tape. This end of the plumb line is of course already provided for the nail if we use a house corner or porch post.

The other end of the sine line, at A, can be found by the use of a screen or target in which a small hole has been bored, and the target capable of being slid along the tape to any desired position. A sketch of this is shown in the figure. For use with the sun a piece of colored glass must cover the pin hole to protect the eye, but with the stars at night an ordinary visiting card suffices.

If now the buckle of the tape is hooked over the nail at C and the tape drawn taut over the head of the observer as is shown in the second degree a position will be found where the nail at the upper end of the plumb line is seen to just bisect the sun's disc. The appearance then will be shown as in the figure, and the head must be moved up and down and the target shifted until the sun is bisected with the *minimum length of tape*. That is, a position will be found as the target sweeps through the arc EF, where the sun seems to rise toward the nail, remains stationary a moment and then falls away. It is at this middle position that the tape is at approximately right angles to the sight line AB, and the length of the sine may then be read off on the tape just opposite the pin hole.

With a little experience this operation of getting the eye, the target, the nail and the sun all in line, becomes an easy one, and if you have been careful in locating these three points of our triangle the observation is finished, and if your plumb line is ten feet, and the sun is on the celestial equator, the angle corresponding to the sine you have measured is your latitude, without further computation.

The sun, however, is on the equator or is "crossing the line" as navigators say, but twice a year—in March and September. Its distance north or south of this position (that shown in the figure) is given for each day in the almanac. It is called the sun's declination. If it is north of the equator—between March and September—this declination must be added to the angle obtained by observation in order to obtain the latitude.

One other small correction is necessary—that caused by re-

*From *Popular Astronomy*, April, 1921, pp. 197-204.

fraction. The sun is never really as high as we see it in the sky, because the light coming from it to the eye is bent down on passing through our atmosphere. This correction for the sun in our latitude never amounts to over two minutes of arc: in summer it is less than one minute. By reference to the figure (1) it will be seen that the angle observed, viz.: ABC is the same as ZBS: that is, we have measured the angle from a point directly overhead down to the sun what is known as the zenith distance. This angle, on account of the refraction, is too small, and therefore this correction is always to be added.

That is all there is to it. The steps are as follows:

1st. Fix two points ten feet apart with the plumb.

2nd. Find the angle between this line and a sight line through the upper point to the sun by measuring its sine.

3rd. To this angle add the correction due to refraction, and apply the sun's declination from the almanac—plus if north and minus if south of the equator.

The result is the latitude.

The above description has been written especially for the

MEASURING THE DIAGONAL

young student who would know something of practical astronomy, but who fears it is beyond him; fears that there is something very mysterious about it, involving higher mathematics, years of application and the use of delicate and expensive instruments beyond his reach. The purpose of this article is fulfilled if it stimulates some one to put his knowledge of plane geometry to practical use, and leads him to further inquiry.

To the reconnaissance surveyor, and to the astronomer it may be of interest to know that this method of determining latitude and time is susceptible of considerable refinement. For instance, the triangle may be referred to the centers of the two nails at the ends of the plumb line, and the center of the pin hole of the target. The buckle at the end of the tape may be deformed so that the tape divisions will read from the nail centers. The diameter of the pin hole cannot be much less than 2 mm. if stars are used. With the sun somewhat less than a millimeter hole is about right. The bisection of the sun's disc seems to be reliable to less than a minute of arc. An error of one thousandth of a foot in the sine for a summer meridian altitude in our latitude affects the angle sought about half a minute of arc. The following circummeridian zenith distances on the sun, using a theodolite to check the angles are submitted:

LATITUDE FROM CIRCUMMERIDIAN ALTITUDES OF THE SUN AS DETERMINED BY TAPE LINE

Springfield, Vermont, August 8, 1920

75th	Watch Mer. Time		Tape Reading	Zenith Distance		Z.D.Red. to Meridian		Latitude		Res.
h	m	s	mm	°	′	°	′	°	′	′
11	41	30	1457.5	27	17.4	27	12.8	+43	19.8	—1.3
	47	20	1453.0		11.9		11.1		18.1	+0.4
	52	10	1452.5		11.3		11.3		18.3	+0.2
	56	50	1453.0		11.9		10.2		17.2	+1.3
0	2	30	1459.0		19.2		12.0		19.0	—0.5
	8	0	1464.5		25.9		11.4		18.4	+0.1
Length of plumb line, 3179.0 mm.							mean	43°	18.5	
Latitude by theodolite,								43	18.3	

The first two columns represent the observations. The third and fourth give the steps in reducing these observations to the meridian. In the fifth column the corrected sun's declination is applied, giving six independent determinations of latitude. The last column shows the amounts by which each determination departs from the mean derived latitude.

Finally, in a triangle the size of the one described a considerable departure from the right angle at A may be allowed before it disturbs the angle sought by as much as a minute of arc.

The writer attempted a further improvement by placing a totally reflecting prism at A so that the observer could look down the sine at a convenient angle against a dark background (case of the sun). He found that any improvement in convenience of posture was offset by the vibration and shifting of the objects viewed through the prism due to its unstable mounting. Even the pentagon prism proved of little help.

GOFIO—A DELICACY FROM THE CANARY ISLANDS

ONE of the curious relics of a very ancient past in the Canary Islands is the popular delicacy known as *gofio*. This consists of wheat which has been first roasted and then ground into flour or meal. It is sometimes eaten in the form of the flour as soon as it comes from the mill, but this requires some skill to prevent its choking the air passages with dust. A common method of preparing it, however, is to knead the dry powder into a cake by adding water and a pinch of salt. The dough thus formed is then pressed into a bag of peculiar form made from the skin of a young goat in order to shape it, after which it can be sliced and eaten like bread. Sometimes the flour is merely added to other foods such as soup, milk, coffee, beer, wine, chocolate, oil, etc., to increase their nutritive qualities. The natives of Teneriffe also have a habit of dipping oranges, bananas, figs, and other juicy fruit in gofio before eating them. That this substance is highly nutritious is shown by the following analysis which we find in an article upon the subject by Dr. L. Lindinger in *Kosmos* (Stuttgart) for March, 1921.

Albuminous matter, 104 gr.; fatty substances, 17 gr.; carbohydrates, 716 gr.; yield in calories, 3,483.30. These figures apply to one kilogram of gofio.

Dr. Lindinger describes the method of preparing gofio as follows: After the wheat has been sorted to free it from impurities, it is spread upon a flat earthen dish on a stove and stirred constantly with a wooden stick, one end of which has been wrapped in cloth, until it has been roasted to a pale brown color. This simple process in which the starch is transformed into easily soluble substances, probably into sugar and dextrine, is all that is required, but in Europe it is more common to use a regular roasting machine like that employed for coffee. After being roasted the wheat is ground in any convenient manner, even in a strong and well made coffee mill.

The same process is sometimes applied to other grains such as barley, rye, and maize and to peas, and in times of scarcity even to fern roots, and to certain seeds and fruits.

Does the Earth Emit Ultra X-Rays?

A New Theory of Radioactivity Suggested by the Swiss Scientist, Jean Perrin

THE essential phenomenon in radioactivity consists in the continual emission of radiations by preparations containing certain remarkable simple bodies, which have been termed radioactive bodies. Radioactivity is never produced in atoms which remain intact; it denotes the disintegration and transmutation of certain ones among them. It is during this disintegration that the atoms emit rays. Thus each atom of radium remains strictly intact until the instant when it is *abruptly* dislocated yielding an atom of helium and an atom of radium emanation.

This is generally explained by assuming that by reason of chances whose average alone can be foreseen, every radioactive atom (or more exactly the nucleus of this atom) is capable of suddenly exploding and dissociating itself into constituents which have been hitherto masked (*i.e.*, into helium and radium emanations in the case of radium), with the liberation of an enormous quantity of internal energy. It is an *explosive atom*, the profound underlying cause which releases the explosion being supposed to be the accidental realization of certain conditions in the interior of the positive nucleus of the atom.

Struck by the analogy between the phenomenon of radioactivity, in which each emission of rays marks the death of an atom, and organic fluorescences, in which each emission marks the death of a molecule, the eminent Swiss scientist, M. Jean Perrin, was led to extend to the field of radioactivity his theory of chemical reactions, namely: that the disintegration of radioactive atoms is produced through the direct influence of a certain radiation. This is an extremely bold theory since it is exactly opposite to the one usually accepted. However, thus far, no fact is known capable of contradicting it.

To begin with, if radioactivity is produced by a certain radiation of external origin, it is necessary to assume, since radioactivity is not affected by variations in temperature, that so far as concerns the intensity of this active radiation we must regard as negligible the intensity (for the same frequency), of the internal radiation of enclosed spaces raised to as high a temperature as we are able to attain.

"It is evident that we cannot be here concerned either with the infra-red rays, those of visible light, or with ordinary ultra-violet rays, all of which manifest their existence otherwise than by the radioactivity excited (*e.g.*, by clouding photographic plates). Furthermore, since no screen and no enclosure either suppresses or appreciably reduces radioactivity, it must be assumed that all walls (and especially the walls of our laboratories) are highly transparent with respect to active radiation. This eliminates not only all the ultra-violet rays as far as the X-rays but also the X-rays themselves and even the γ rays—in other words all known rays of light are eliminated."

"But when we approach by increasing frequencies the limits of this known light we are well aware that the power of penetration increases. X-rays long ago excited our surprise by showing themselves capable of traversing sheets of metal, and γ rays of a frequency altogether not much greater, are capable of traversing, without being much diminished, blocks of lead from 10 to 20 cm. in thickness. It is not unreasonable to suppose that beyond these γ rays there may exist rays of light much more penetrating, which it is possible to conceive of as producing the phenomena of radioactivity."

These rays cannot proceed from the sun by reason of the fact that measurements made by Madame Curie have proved that radioactivity does not vary during the night, but "it is quite possible that this active radiation issues from beneath our very feet, from the hardened center of the planet itself."

ULTRA X-RAYS

M. Perrin proves in fact that it is perfectly reasonable and logical to assume that the earth is constantly emitting *ultra-X-rays*, which are much more penetrating than either X-rays or γ rays, so much so, in fact, as to be able to traverse a thick layer of rocks—and that *these ultra X-rays produce the various forms of radioactivity observed by us.* It is needless to remark upon the fact that the internal radiation of our furnaces could in no way augment the intensity of these rays and, consequently, could exert no effect upon the rates of disintegration.

Under the action of these ultra X-rays, atoms might be capable of undergoing changes quite comparable to the ionization which they undergo under the influence of the X-rays; but by reason of the much higher frequency the ionization would be much more intensive if it were produced and might even have an effect upon the positive nucleus of the atom, in such a manner as to occasion a real transmutation.

The calculations made by M. Perrin have led him to attribute to the ultra X-rays a frequency of the order of 3×10^{21}, which corresponds to a wave length $\lambda = 10^{-11}$ cm., only one five-millionth as long as that of yellow light. This gives us a satisfactory result: Radiations which are as penetrating compared to X-rays as are the latter compared to visible light, must indeed have an exceedingly high penetrative power—a power quite sufficient, doubtless, to enable them to traverse the crust of the earth where, perhaps, they would run scarcely any risks of being absorbed except by precisely those atoms which they are capable of causing to disintegrate.

An advantage of this new theory over that of the explosive atom lies in the very fact that it suggests the possibility of making experiments and verifications; thus, the idea presents itself that a radioactive substance may be partially protected against the ultra X-rays by means of a screen which is highly radioactive—a screen which is, indeed, made of the same substance and capable, therefore, of absorbing the same rays; to mention one instance in particular, measurements might be made in radiferous territory.

Another idea which suggests itself is that experiments might be made at various altitudes, since the intensity of the radiation emitted by the earth ought theoretically to decrease with the height, following exactly the same law as that which governs the strength of gravity. In this case the average life of a radioactive element ought to increase with the altitude in inverse ratio to the strength of gravity. When we remember the great heights which it is now possible to attain by means of an airship it will be readily seen that it would be possible to make a critical experiment so soon as we have become positively certain of the thousandth part in the measurements of radioactivity. It already seems probable that we are not very far from this goal.

This new theory does away with the peculiar character which has been believed to be connected with atomic disintegrations, which are to all appearance very strongly exothermic, and the molecular dissociations, which are endothermic. As a matter of fact the breaking up of radium, far from liberating energy, as supposed, absorbs an enormous quantity of it, according to Perrin's view—but the absorbed energy, none of which is evident to us, is radiated by the earth and does not come from our foci. The energy emitted in the form of α, β or γ rays is not borrowed from the atom at all, but merely forms a portion capable of being utilized by us of the energy borrowed from the ultra X-rays, another portion having arrived to increase the internal energy of the transformed matter.

M. Perrin concludes: "Thus the radioactive atom is not to be considered as being analogous to a magazine of dynamite—*it is not explosive.* It is, on the contrary, a very stable system which cannot be split up except by a prodigiously difficult *tearing apart.* So that if we accept this view it is necessary to revise all those conclusions wherein the sign of the energy

is supposed to play a part in the radioactive transformations."

This observation enters into the explanation furnished by Langevin of the discrepancies of the atomic weights with respect to the whole numbers which we ought to have, if it be true according to Prout's hypothesis that all atoms are derived from a single element, such as hydrogen for example, in a more or less condensed state. Such differences can be explained by means of one of Einstein's theories, according to which energy possesses mass—or to state the matter more exactly, the mass of an object which either emits or absorbs energy is correspondingly diminished or increased in grams by the quotient w/V^2 of the number w of ergs lost or gained by the square of the velocity of light.

When the energy w is that of an ordinary chemical reaction, this variation of mass is entirely negligible, and we know, in fact, as was discovered by Lavoisier, that the mass is the same before and after the reaction. But in the case of a radioactive transformation the energy w is so great that the variation of the mass ought to become appreciable. For example, the transmutation of radium per atom-gram ought to produce variations of the magnitude of the centigram.

However, as yet no one has paid any attention to the *signs* of the variations. If the radioactive transformation were really explosive in nature, as has hitherto been thought, there should be a loss of mass involved. But if, on the other hand, for the reasons set forth above, this disintegration is *endothermic, i.e.*, accompanied by a gain of energy, then it will be accompanied by an *augmentation of the mass.* Reciprocally, an atomic condensation will be accompanied by a loss of mass. This, indeed, is probably what takes place if we assume it to be a fact that all bodies are formed of hydrogen. We need only to read the list of atomic weights to see that three gram-atoms of hydrogen weigh 3 centigrams more than 1 gram-atom of helium; in the same way 16 gram-atoms of hydrogen weigh 12 centigrams more than a gram-atom of oxygen and so on. This is why Perrin says:

"These numbers are of suitable magnitude and *of the predicted* sign. They are *inexplicable* under the theory of the explosive atom."

In the above paragraphs we have presented a brief but complete digest of Professor Perrin's brilliant article in the Revue du Mois (Paris), for Feb. 10, 1920. While this abstract, for which we are indebted to the Revue Scientifique (Paris) for Feb. 12, 1921 will be sufficient to give the general reader an idea of the boldness of Prof. Perrin's theory and its importance to the new science of radioactivity we are adding for the special benefit of those particularly interested in this new science a detailed translation of a portion of the original article. Our readers are already familiar with the brilliant character of Prof. Perrin's researches upon phosphorescence and fluorescence and with his novel and ingenious theory concerning the laws of chemical reaction. Daring as his concepts are they are based upon years of study and personal research. His article is dedicated, by the way, to J. H. Rosny, the elder, the author of the well-known work of fiction entitled La Force Mystérieuse.—EDITOR.

NEW THEORY OF RADIOACTIVITY DISINTEGRATION BY TEARING APART

* * * Now that we understand the mechanism by which temperature influences the velocity of reaction, we can readily imagine conditions in which a chemical reaction might remain unaffected by any variations of temperature to which it is within our power to subject it. Thus, the fluorescence excited by sunlight in a solution of uranin is the same at the temperature of melting ice and at that of boiling water, because the quantity of active light, added by the internal radiation to the solar radiation, is entirely negligible within these limits of temperature.

But if radioactivity were produced by a certain wave length of light, as chemical reactions are, it would be necessary in the same way that this light should be of external origin, and that with respect to its intensity we might regard as negligible the intensity, for the same frequency, of the internal radiation within the limits of the highest temperatures which we are able to attain.

It is evident, therefore, that such a form of light could not be visible light, nor infra red, nor ordinary ultra violet rays since these manifest themselves in other ways than by exciting radioactivity. * * * Furthermore, since radioactivity is practically unaffected by screens and by distance the theory requires us to assume that all walls are transparent to the active radiation * * * thus eliminating all known light.

But when we approach by increasing frequency the limits of this known light, we are aware that its power of penetration increases. * * * It is not unreasonable to believe, therefore, that beyond the limits of the γ rays there may be more keenly penetrating forms of light and to assume a possibility that these may produce the phenomenon of radioactivity. As we have seen, experiments have shown these rays cannot proceed from the sun. But another origin is possible, and one which apparently has hitherto occurred to no one:

It may be that the active radiation springs from beneath our feet from the glowing center of our own planet.

THE ULTRA X-RAYS

We shall see that if we assume that the earth continually emits ultra X-rays far more penetrating than either X-rays or γ rays, and that these ultra X-rays produce the various sorts of radioactivity known to us, the conclusions derived from such a theory are entirely logical. * * *

Under the action of these ultra X-rays, atoms may undergo changes comparable to the ionization produced in them by X-rays. But, because of the much higher frequency and of the magnitude of the corresponding quantum $h\nu$. the ionization in case it were produced, would be much more profound.

In the first place certain electrons which are already very deeply placed and which the X-rays are incapable of tearing away, might be projected towards the exterior with velocities characteristic of the atom, as in the case of ordinary ionization, thus forming a "spectrum" of β rays like that which Danysz discovered in radium preparations.

However, in the positive *nucleus* of the atom there is no real transmutation, no disintegration. Sooner or later, and assisted if need be by certain radiations, the atom which has become positive will recover the electrons which it lacks and will rearrange itself (with fluorescence) into a neutral stable system, reproducing the primitive atom. (Is this true perhaps in the case of potassium which emits β rays and yet appears not to be transmuted?)

But the nucleus itself would be modified or broken in the case of transmutation. And the ultra X-rays might then be capable, at the expense of enormous labor, of tearing away one or another constituent. This reaction is similar to ionization, but this time positive centers and not electrons alone would be expelled.

* * *

We are obliged to omit here the mathematical equations by which M. Perrin supports his theory. His general conclusion, based upon elaborate calculations, is that the frequency of the exciting ultra X-rays correspond to a wave length which is only the 20-millionth part that of yellow light.—EDITOR.

* * *

The other radioactivities give us figures representing corresponding magnitudes.

This result is most satisfactory. Radiations of such high frequency as these must be extremely penetrating, enough so doubtless to pass through the crust of the earth, where, perhaps, they are not absorbed except by those very atoms whose disintegration they occasion. At the same time this theory adds 10 more octaves to the diapason of luminous radiation, so that we see

it sweep through about 30 octaves, beginning at the extreme infra red.

PROBABLE VARIATIONS AND RADIOACTIVITIES

Our theory is developing with coherence but, of course, we must demand more than probabilities to convince us. An advantage of the new theory over that of the explosive atom lies in the very fact that it suggests experiment and verification. * * * It is by no means certain, however, that the radiation from the earth always possesses the same intensity at any given spot, and if the central fires are subject, as is probable, to local variations, recalling sun spots, then corresponding variations in radioactivity can be predicted.

THE ENDOTHERMIC NATURE OF RADIOACTIVITY

* * * Far from the disintegration of radium liberating energy it *absorbs* an enormous quantity, but this absorbed energy is radiated by the earth and not by our foci. The energy emitted in the form of α, β or γ rays * * * is merely borrowed from the ultra X-rays. Hence the radioactive atom is *not explosive*, but, on the contrary, a very stable system which cannot be disintegrated except by a prodigious tearing effort; hence we must revise all those previous conclusions in which the sign of the energy of radioactive transformations is supposed to play a part.

If, contrary to what we have previously supposed, the radioactive disintegration is *endothermic* on a colossal scale, then the inverse reaction consisting for example in the formation of radium from radon and helium would be exothermic on an equally huge scale, and would approximately resemble in magnitude the transformation of ozone into oxygen. And in the same way that this destruction of the ozone, though exothermic, requires the action of suitable radiations and consequently, practically never occurs within opaque boundaries which are too cold. In the same way the association of radon and helium to form radium may require either a suitable external radiation or, possibly, a minimum temperature which it is probably beyond us to attain; (furthermore, the return may be effected by stages, as in the case of phosphorescence). One can already guess and we shall soon indicate what this leads up to.

PROTO-ATOMS, UNITS OF MATTER

Radioactive transformations have revealed to us that there are some atoms, at least, which are very complex, and which do not differ from ordinary molecules except by the magnitude of their energy of formation. Reciprocally, we have discovered, and not without some stupefaction, that at a temperature sufficiently low, *i.e.*, with a very poor internal radiation, *molecules may exhibit certain properties of atoms.* Thus, below 30 deg. cent. absolute diatomic hydrogen assumes the specific heat common to all of the monatomic gases, such as argon (Eucken).

From those elements which really deserve the name of atoms and which we may term *proto-atoms;* there are built up all the atoms and all the molecules, and these proto-atoms, which resist the most powerful efforts of light, include only a small number of kinds. The negative electron, a universal constituent of all atoms, is one of these proto-atoms. The positive nucleus of hydrogen is another one. Perhaps this is true also in the case of the positive nucleus of helium which still remains after more than 20 radioactive disintegrations. And with respect to helium it is startling to find that in the list of atomic weights of non-radioactive bodies, 10 of the differences are equal to 4, which is the atomic weight of helium.

Possibly even the nucleus of helium is complex. Rutherford * * * regards it as formed by 4 hydrogen nuclei and 2 electrons * * *.

The nucleus of hydrogen and the electron (the latter having a mass only about one two-thousandth part as great), would then be the only proto-atom, and here we come across an ancient hypothesis, known under the name of Prout's Law, to the effect that in the last analysis all simple bodies are merely more or less condensed forms of hydrogen. * * *

If it be a fact that every atom is made up of nuclei of hydrogen and electrons of relativity negligible weight, then it would seem that all atomic weights should be multiples of that of hydrogen—and as a matter of fact this is approximately true in the case of a large number of elements, though there are some indubitable exceptions.

I will not here state the reasons which lead us today to believe that in these exceptional cases (magnesium, silicon, chlorine, etc.) we are dealing not with a single, simple body, but with a mixture of simple bodies having different atomic weights and yet possessing properties so similar that it is extremely hard to separate them. In this concept, which we owe to Soddy, and which appears continually more probable, natural chlorine, for example, is held to be a mixture of *isotopic* chlorines, which are practically inseparable and which verify Prout's Law separately. But I should like to emphasize just here another thing not yet pointed out but which lends support to my theory concerning radioactivity.

EXPLANATION OF DISCREPANCIES WITH PROUT'S LAW

This section was sufficiently covered in the preliminary abstract to which the reader is referred.—EDITOR.

THE INFLUENCE OF COSMIC CONDITIONS

The theory set forth in a recent article appears to involve consequences which are of interest from the viewpoint of astronomical physics and cosmogomy.

We have already observed that radioactivity ought logically to change with altitude. Instead of confining ourselves to those variations of latitude which are accessible in practice, let us suppose that the radioactive substance grows more and more remote to infinity. In this case the intensity of the ultra X-rays which it receives from the earth would incessantly diminish in inverse ratio to the square of the distance from the center of the earth. When the radioactive body passes the plane of the orbit of the moon, the ultra X-rays emanating from the earth will have become so feeble that if they alone be taken into consideration, the average life of the atom of radon, instead of being a period of six days would have been lengthened to one of sixty years. As a matter of fact it then becomes necessary to take into account the ultra X-radiation which undoubtedly emanates from the sun and which, having undergone scarcely any diminution because of the enormous distance of this star, may perhaps then be the predominant factor. Let us assume, according to what seems to be the fact, that upon the earth the ultra X-radiation coming from the sun is less than one-hundredth part of that proceeding from the earth; then at the distance in question the average life of radon will be more than two years in length. If we now suppose that our radioactive body continues to grow more remote from the solar system, the probability of its disintegration will constantly diminish, so that in the intersiderial spaces it will become practically eternal, since taking into consideration the vastness of interstellar distances its life will be at least a million times as great as upon the earth. Like other reactions radioactivity will be benumbed amid the cosmic dust which, swung by the stars, as we see in the tails of comets, becomes inert and cool as it passes from one stellar system to another; yet, meanwhile, it bears within itself the possibility of being reawakened when it reaches some far distant world.

THE AURORA BOREALIS—CORRECTION

PROFESSOR STÖRMER'S article on the above subject which appeared in our July issue, had to go to press before the author's proofs were received. He notes the following correction: On page 12, first column and seventeenth line from the bottom of the page the distance "fifteen million kilometers" should, of course, read *a hundred and fifty million kilometers.*—EDITOR.

The Deadly X-Ray and the Innocent Bystander

Should Insulating Sheets of Lead Be Required by Law for Rooms Employing X-Ray Apparatus

Both in this country and abroad the public has recently been deeply shocked by the cruel deaths of some of our most brilliant pioneers in the study of the X-ray. One of the most recent of these was the French scientist, Leray, and apropos of his dreadful death there has been much discussion in the French press as to whether such premature perishing of radiologists is inevitable or due to carelessness bred by familiarity. Dr. G. Contremoulins, one of the most eminent radiologists in France, and head of the principal laboratory of radiography connected with French hospitals, has made the disturbing declaration that because of the greater penetrating power of the radiations now in use not only operators and assistants are in danger but even employees in adjoining rooms. So grave does he consider this danger that he urges the passage of a law compelling all radiological "stations" to be encased in thick slabs of lead to prevent the rays from passing through the walls after they have acted upon the patients under treatment.

Because of the great importance of the subject we shall here attempt to give an accurate idea of the facts upon which M. Contremoulins bases his fears and of the remedy he proposes.—EDITOR.

DURING the last few months Dr. G. Contremoulins, the distinguished French radiologist, who holds his clinics at the Hospital Necker, and who was in charge, during the war, of this branch of the military service, has laid before the French Academy of Sciences certain very interesting communications setting forth in detail experiments made by him with the purpose of demonstrating that the X-rays now in use for medical and other purposes are so much more powerful than those in use in the early days of science as to be dangerous even for the public whose business brings them into the neighborhood of X-ray apparatus, even in adjoining rooms. These communications, which were presented by M. Lippmann, aroused a heated controversy, some of it so acrimonious, indeed that their distinguished author prayed that learned body to appoint a commission to examine into the justice of his claims, remarking very truly that, in a science so new, it is certainly best to be upon the safe side, particularly in view of the number of victims this mysterious force has claimed during the brief quarter of a century or so since they were discovered.

The following paragraphs consist chiefly of excerpts from M. Contremoulins's own writings as published in the Paris press and in the *Comptes Rendus* of the Academy of Sciences. Writing in *Le Démocrati Nouvelle* (Paris) for April 10, 1921, he says:

"Since the discovery of the X-rays in December, 1895, they have been used in many laboratories and medical cabinets as well as more recently in the metallurgical industry and in that of precious stones. But their use is most general in medicine, and all operators are, as a usual thing, exposed to the injurious effect of these radiations since the protective measures furnished them by industrial manufacturers are only too often dangerously ineffective and most deceptively so. Young radiologists especially those born of the war, take no heed of the experience acquired by their elders, being quite convinced that the glasses, gloves and aprons containing lead offer a perfect protection—they even imagine that strictly speaking they might get along without these.

"Like a child which hides behind a wooden door to shield itself from the bullets of a machine gun, our young radiologists believe they are safe when they have donned their gloves and examine their patients behind a sheet of lead glass. But, unfortunately, these enable them only to avoid those superficial skin affections caused by the most absorbable rays of the spectrum.

REGIONS OF DUCTLESS GLANDS

"But they receive alas, those other radiations which are more penetrating, and these slowly produce lesions of all the ductless glands in the body, whose internal secretions we now know to be of such vital importance in the bodily economy.

"It is to such lesions that the lamentable death of Leray, Infroy, and so many other students have been due.

"But is it only the operators themselves, we may ask, who are subjected to these attacks from the radiations received in the course of their researches?

"Alas, no! Among the X-rays there are some at the far end of the spectrum which are so highly penetrating that the walls and floors of our laboratories and cabinets present but slight obstacles, so that persons residing next them, whether as patients or as mere tenants, may become our innocent victims despite themselves.

"The gravity of this becomes apparent when we remember that recent researches in the treatment of cancer have shown that it is necessary to irradiate tumors for 12 or 15 hours consecutively with extremely penetrating rays. We may well ask ourselves, then, with the deepest concern what will be the fate of our neighbors on the floors below us at the end of a few months? And yet to secure protection from these dread effects is a comparatively easy matter: X-rays are absorbed by various bodies in direct proportion to their atomic weight and to the square of the mass. Now building materials have a very high atomic weight—*e.g.*, that of lime is 40.

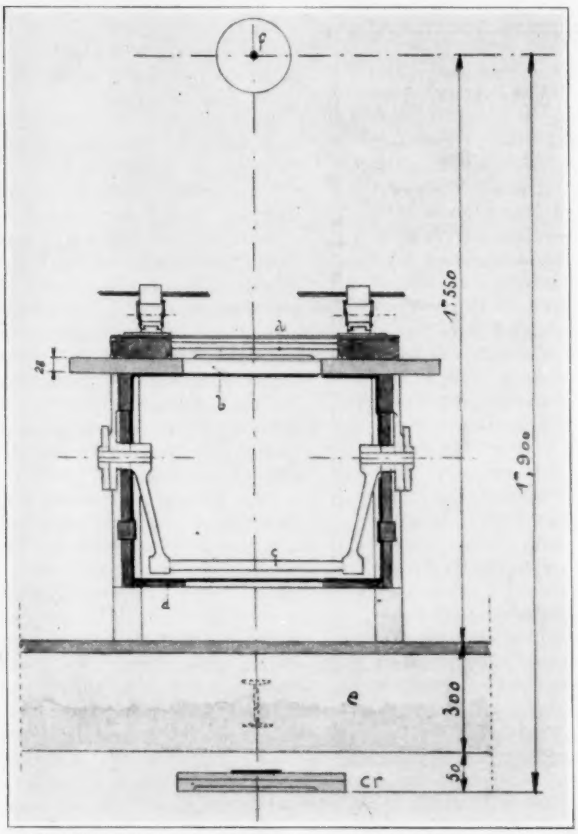
"On the other hand we have at our disposal as a means of protection a metal quite perfect for the purpose, namely, lead, which is not only cheap and readily obtainable by every one, but has the prime qualification of an atomic weight of 207.

"Our remedy, then, is merely to cover the walls and floors of our X-ray cabinets with sheets of lead whose thickness should vary from 6 to 10 mm., according to the power of the source of irradiation. This will remove all risk to our neighbors and our assistants, while as to the operators themselves, they should manipulate the apparatus from within a cabin encased in sheets of lead, observing their patients in a mirror."

After making this statement of his views M. Contremoulins urges that the handling of X-ray apparatus should be classed among the dangerous trades and its practice carefully regulated by law. At the same time he admits that his younger colleagues may raise strenuous objections to any sort of legal restriction. He hopes therefore to rouse the public to the dangers to which at present it is heedlessly exposed.

He justly observes that since the recent deaths of X-ray operators have occurred chiefly among those savants who began the study of the subject some 10 or 15 years ago, we should at least defer a final conclusion upon the matter for the same length of time, during which extensive experiment upon the matter should be made. Meanwhile it is the part of prudence to observe such precautions as may eventually prove indispensable, even if the danger be not yet fully proved. He observes: "Since I was among the first to experiment along this line, I shall all too probably meet the same end as my defunct col-

leagues, yet I hope that at least my own experience may serve as a warning to others. The searching behind a screen for the presence of foreign substances in a wounded soldier's body which I practiced during the war with only the army



ARRANGEMENT TO DETERMINE PENETRATION THROUGH THE FLOOR OF THE LABORATORY

f, coolidge tube; a, plate holder; b, marble, with lead facing; c, steel bar; d, lead sheet; e, floor and ceiling; cr, plate bearing test pieces

equipment at my disposal which did not afford adequate protection resulted in my being affected by an erythema of the hands, justifying my predictions and my fears.

"But I wish to emphasize that in my civil practice I have had no accident of any sort among my patients, my collaborator, my nursing staff, or myself, in spite of the enormous amount of work done in my laboratory, including from 70 to 100 examinations per day. The reason for this is that in 1912, after the death of Blanche Veinsan at Saltpétrière, the board of directors finally granted me the lead sheathing for the walls for which I had been begging them for several years.

"This experience of 25 years is the best justification of my theories and I oppose it to the unfounded statements of my opponents, since the coffins of my unhappy colleagues have not sufficed to support my views."

DETAILS OF THE EXPERIMENTS MADE

"The installation of an operating room for radio-surgical purposes on the ground floor of my laboratory at the Necker Hospital, had as a result the exposure of my patients, of the nursing staff, and of the assistants in residence there, to the crossed radiations of three X-ray tubes operating simultaneously for several hours at a time. I deemed it advisable, therefore, to make experiments in order to determine what thicknesses of lead were necessary to insulate the two stories above from their radiations.

"I made use of a Coolidge standard X-ray tube and Jougela metro-radiographic sensitive plates, together with a reinforcing screen from the firm of Caplain-André which reduced the time required for exposure to one-twentieth that ordinarily required.

NATURE OF FLOOR AND CEILING

"The ceiling above was composed of iron beams and oak joists with a flooring which was likewise of oak; the ceiling underneath this floor consisted of plaster 10 cm. thick, the spaces between the joists being filled with rubbish. The total thickness of combined floor and ceiling was 30 cm.

"*First Experiments.*—The focus of the Coolidge tube occupied its usual place above the operating table 155 cm. above the ground. Under the floor at a distance of 190 cm. the radiographic carriage held the following test pieces: A piece of lead 3 mm. thick, Benoist radio-chromometer and a Contremoulins radio-photometer. In order to strike the surface of the sensitive plate the X-rays were obliged to traverse the objects enumerated below in the order of their distance from the focus:

"*a.* A slide-block and a plate-holder both of wood, having a combined thickness of 72 mm. and placed at a distance of 75 cm. from the focus.

"*b.* A portion of a marble slab 28 mm. thick covered with portion of the table, 135 cm. from the focus.

"*c.* A bar of steel 30 mm. in diameter, 130 cm. from the focus.

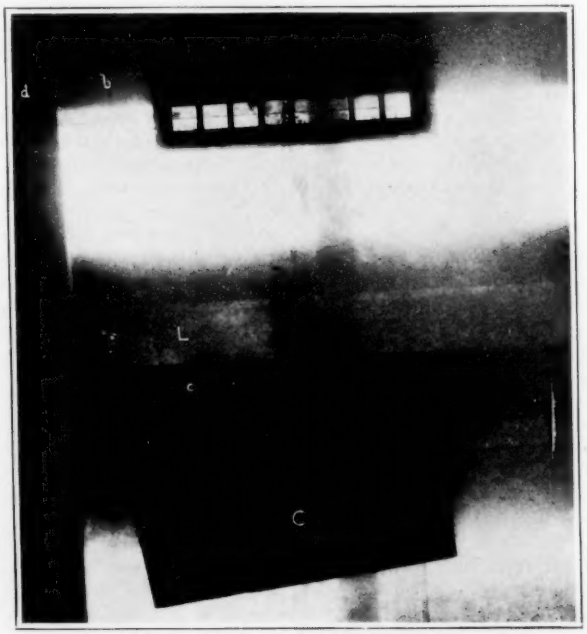
"*d.* A sheet of lead 3 mm. in thickness protecting the lower portion of the table, 135 cm. from the focus.

"*e.* The combined floor and ceiling described above.

"*f.* The test pieces held by the radiographic carriage which was placed at a distance of 190 cm. from the focus.

"Length of spark, 17 cm.; milliamperes, 2; time of exposure, 10 minutes. This is equal to a normal functioning of 2½ minutes with 8 milliamperes.

"*Result.*—The slide (*a*) yields no image. The sheets of



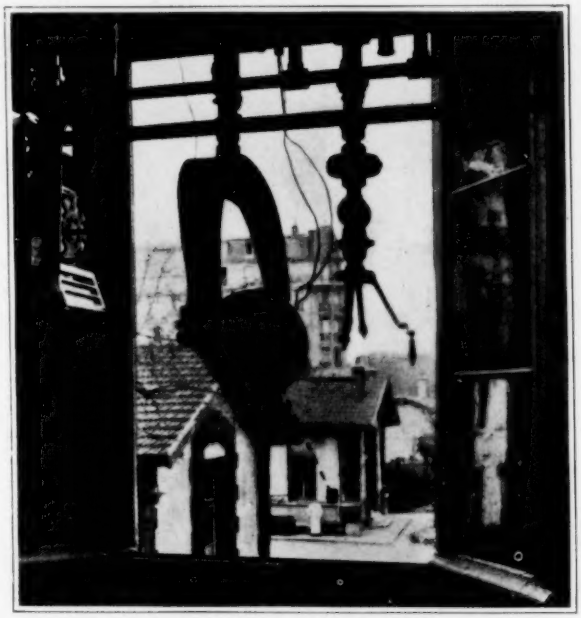
RESULT OF EXPOSURE THROUGH THE FLOOR

b and d, lead on marble; C, lead plate; e, steel bar; D, radio-chromometer; E, radio-photometer

lead (*b* and *d*) appear to be partially traversed; the sheet of lead (*d*) yields a clearly defined image of its edge underneath the portion protected by the marble and by the upper sheet of lead (*b*). The image of the radiophotometer is complete underneath the portion protected by the sheet of lead 3 mm. thick

and the marble (*b*); it is due in large part to direct radiation, judging by the clearly defined character of its edges. The steel bar (*e*) is traversed; the sheet of lead resting upon the chassis is cleary visible beneath its projection. An image which appears to correspond to that of an iron beam of the ceiling shows that the latter must have been powerfully traversed.

"We conclude that a mass of lead placed at a distance of 190 cm. from a 17-cm. spark Coolidge tube must not be less than 6 mm. in thickness in order to furnish effective protection. There should be no interruption of its continuity so that diffusion and secondary rays may be avoided.



X-RAY TUBE MOUNTED BEFORE THE OPEN WINDOW OF THE LABORATORY

SECOND EXPERIMENT

"The conditions of the first experiment remained the same in the case of the upper story. In the lower story the radiographic carriage was placed upon the table, whereupon the assistant arranged the plates during the functioning of the tube. This table was 460 cm. from the focus. The following test pieces were placed upon the carriage. At the corners pieces of metal of varying thicknesses (a piece of lead 3 mm. thick; a piece of steel 3 mm. thick; a piece of cast iron 100 mm. thick; an iron clamp). In the vicinity of the lead there was a shoulder blade. A dried skull rested upon the carriage base downward partly covering the piece of steel. In the center were the radio-chromometer and the radio-photometer. Upon the edge beneath the piece of cast iron and the shoulder blade there was a steel wrench.

"Length of spark, 17 cm.; milliamperes, 2; time of exposure one hour. This is equal to a normal functioning of 15 minutes with 8 milliamperes.

Result.—The sensitive plate, three-quarters of which was protected by the sheet of lead attached to the marble of the radiological table received an impression throughout its whole extent. This sheet of lead, 3 mm. thick allowed a portion of the direct radiation to pass; the piece of cast iron, the clamp, the radio-photometer and the wrench were clearly visible; the radio-chromometer yielded a faint image. Upon the portion of the plate which received the radiation filtered through the floor alone we could see very clearly defined the opaque mass of lead and the more transparent mass of steel. The skull yielded a perfect image through the latter. The shoulder blade was perfectly visible throughout its whole extent in spite of its very slight thickness.

"At this distance of 460 cm. and after being filtered through the floor the radiations which struck the plate were still easily absorbed, which is proved by the fact that it was possible to obtain the image of the shoulder blade. Obviously, therefore, they constitute a source of danger to the human organism.

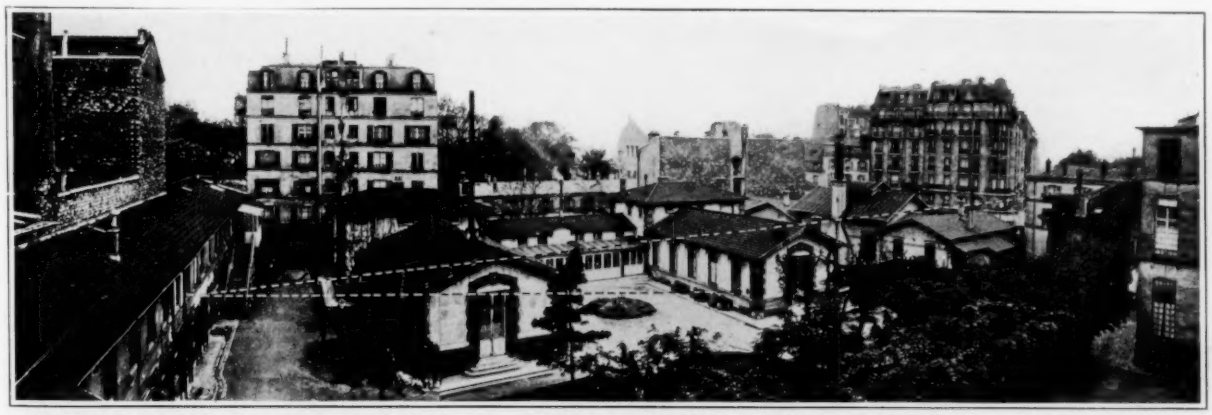
"We know that photographic plates are but slightly sensitive to X-rays; apparently those X-rays which have very short wave lengths ought not to produce any impression. Hence, they escape registration by this graphic method. It would be advisable to seek for their presence by the more sensitive method of ionization.

"For intensities which do not exceed 17 cm. in length of spark and 10 milliamperes, a lead casing 6 mm. thick placed at a distance of 2 m. from the focus would appear *a priori* sufficient. At any rate this is the minimum which should be exacted. These intensities correspond to those utilized in medical practice for the examination of patients (radiography-radioscopy).

"As for the intensities which are required in profound radio-therapy, in the treatment of cancer, they are represented in France by a length of spark of 25 cm. for from 12 to 15 consecutive hours of exposure, and in Germany by a length of spark of 120 cm. for 5 consecutive hours of exposure. The radiations produced by such potentials is endowed with a power of penetration which should probably be classed in the vicinity of the spectrum of radium. These sources of energy cannot be installed in the heart of cities without involving the gravest danger to their inhabitants. It is a matter of great urgency that proper measures should be taken to protect them.

"I completed the researches above described[1] by making cer-

[1]Published in *C. R. Ac. Fr.* for May 2, 1921.



MAKING LONG DISTANCE X-RAY EXPOSURES. THE LOWER DOTTED LINE SHOWS AN EXPOSURE AT A DISTANCE OF 40 METERS (131 FEET) AND THE UPPER ONE AT 80 METERS (262 FEET)

RESULT OF AN HOUR'S EXPOSURE AT A DISTANCE OF 40 METERS

TELERADIOGRAPH OBTAINED AT A DISTANCE OF 80 METERS FROM THE X-RAY TUBE, WITH AN EXPOSURE OF FOUR HOURS

tain further experiments of which a brief résumé is given below:

"*First Experiment.*—I sought to find out whether it was possible to detect the presence of X-rays coming from one of my lamps behind the wall of a pavilion for patients placed opposite to my laboratory. I purposely selected the one at the greatest distance. This wall, which is 50 cm. thick, is built of brick and stone, and is situated at a distance of 15 m. from the focus of a standard Coolidge tube which irradiates it obliquely from an angle of about 40 deg.

"Radiation employed: Length of spark, 17 cm.; 2 milliamperes; time of exposure, 4 hours. The plate used was of the metro-radiographic type and is placed in contact with a reinforcing screen reducing to 1/20 degree. A strip of black paper interposed between the screen and the sensitive surface served as a control to eliminate the clouding due to the development. The plate presented a very apparent general impression *except for that part where the control strip of black paper was situated.*

"*Second Experiment.*—Two plates prepared as indicated above were exposed behind human bones and articles made of metal at a distance of 40 m. from the focus.

"Radiation used: Length of spark, 17 cm.; 2 milliamperes; time of exposure one hour. The plates yielded images which are correct and remarkably clear cut.

"*Third Experiment.*—A plate prepared as described above was placed behind a dried skull, a partly emptied crab, a glass bottle containing a solution of copper sulphate (30 per cent), a radio-chromometer, and a piece of lead 3 mm. thick. The ensemble was placed at a distance of 80 m. from the focus.

"The radiation employed: Length of spark, 17 cm.; 2 milliamperes; time of exposure, four hours. The plate yielded a correct image. These times of exposure were calculated from a standard photographic plate which received an impression at a distance of 2 m. in ten seconds, with a length of spark of 17 cm. and 2 milliamperes.

"It can be demonstrated that the negatives obtained at distances of 2 m. and of 40 m., respectively, are identical. That at 80 m. is fainter, but we must take into account the fact of the 24 minutes deducted from the normal time of exposure and the interposition of a fir tree situated at a distance of 20 mm. in the path of the rays.

"*Conclusion.*—It appears from the foregoing observations first that the range of the radiations emitted by tubes of the Coolidge type is quite considerable; and second, that they possess the property of being decomposed by the bodies which they traverse in comparable proportions, whatever the distance may be.

"It is evident, therefore, that the bundle of rays preserves in large part its initial heterogeneity since the images it furnishes of the same bodies are comparable at respective distances of 2 m., 40 m., and 80 m. At 40 m. a linen compress still yields a contrasting image.

"Under the conditions which we have just described there can certainly be no *a priori* denial that they exert a biological influence at a distance. The latter probably decreases in proportion to the density of the radiation, *i.e.*, according to the square of the distance."

A SERUM TO DECREASE WHITE BLOOD CORPUSCLES

AT a meeting of the French Biological Society, held January 8, 1921, a description was read of an unusually interesting experiment made by M. G. Lindstroem. By injecting into the veins of a sheep white blood corpuscles or leucocytes taken from the abdominal cavity of a rabbit he obtained a serum, which when injected into the veins of the rabbit occasioned in this animal a marked diminution in the number of the poly-nuclear leucocytes and which even exerted a toxic effect when given in large doses. The author of the experiment observed, moreover, that the same leucolytic serum when employed in doses much smaller and often repeated, ceases to have an injurious effect but exerts a stimulating action upon the formation of the white corpuscles and even of the red corpuscles.

This interesting fact suggested the idea to M. Lindstroem that it might be possible, in two cases of pernicious anemia under his care, to excite the hematopoetic function of the spinal marrow in this way, but the attempts were without results. However, he was somewhat more successful in an attempt to treat the leucenia with a leucolytic serum prepared with the white blood corpuscles of two patients; the action of this serum when injected into the muscles was distinctly favorable for some length of time, but unfortunately the destructive effect of the serum proved to be only temporary, since at the end of three months the malady resumed its course.

The Fallacy of "Ptomaine Poisoning"

The Bacteria Which Are Really Responsible for Most Cases of Food Poisoning

By Frank L. Healy

IT is high time that justice were done the long-suffering ptomaines. For eighty years or more they have been made to bear, quite unjustly, the burden of responsibility for food poisoning outbreaks. Much has been done to exonerate the ptomaines, and to expose the real culprits, by Dr. William G. Savage, an English physician and public health officer, who has devoted many years to the study of food poisoning outbreaks and whose book "Food Poisoning and Food Infection" has recently appeared.

The history of the origin of the ptomaine theory of food poisoning provides a typical example of the fallacy of hasty generalization based on insufficient data. For this reason it might be worth while to consider how the theory arose and what discoveries led to its acceptance as an explanation of food poisoning; for this explanation certainly was generally accepted by medical men and scientific text-books, and the term "ptomaine poisoning" persists even today. Briefly the story is this: Certain scientists found in the early part of the 19th century that the injection of watery extracts of putrefying meat into the veins of various animals frequently produced death. They succeeded in isolating from putrid meat many chemical compounds which they found to be highly poisonous to animals by inoculation into their veins. On account of their chemical similarity these substances were grouped together and called ptomaines. On the basis of these experiments the generalization was made that the ptomaines were responsible not only for the harmfulness of tainted meat, but for food poisoning in general. And even today, in spite of the existence of readily available evidence to prove the fallacy of this explanation, it is accepted as adequate by many medical men.

It cannot be too emphatically stated that the ptomaine theory has been definitely proved to be without scientific foundation as an explanation of food poisoning; and the reasons follow: In the first place, in most cases of food poisoning outbreaks, the food at the time of eating shows no signs of putrefaction, and is in no way offensive to the senses of taste or smell. The onset of symptoms occurs suddenly from three to forty-eight hours after the food has been eaten. It is patent that these symptoms could not have been caused by the presence of ptomaines in the food consumed, nor could they have been formed in the food after eating for the reason that ptomaines are end products of putrefaction. They are not formed in appreciable amounts until putrefaction has been in progress for a week or more, before which time the food has already become offensive to the senses. Certainly no person mentally normal would eat food which already showed unmistakable signs of decay as regards appearance, taste and odor. Furthermore, the general toxicity of ptomaines has been exaggerated. It was assumed, because these substances proved poisonous to animals when injected into their veins that they must also be poisonous to man when taken through the mouth. This assumption is not wholly justified in the light of feeding experiments which have been performed with ptomaines. Many of them can be eaten in relatively large quantities without producing toxic results. Among the ptomaines of this type can be mentioned methylamine which has been obtained from decomposing herring, haddock and other fish. Enormous doses of cadaverine when fed to dogs failed to produce toxic symptoms. As regards those ptomaines which have been found extremely toxic by injection, it has been found in the case of neurine that in order to produce the same physiological effect, ten times as great a dose was needed when administered by the mouth as when administered by injection under the skin. Muscarine, the toxic element in poisonous mushrooms, has a very similar action. These peculiarities suggest the existence of some agency in the gastro-intestinal tract capable of resisting the entrance of these ptomaines into the circulation. There remains the additional fact that the symptoms produced by taking ptomaines into the human body by the mouth are not those found in food-poisoning outbreaks. The term "ptomaine poisoning," then, is clearly incorrect when applied to food-poisoning outbreaks.

If ptomaines cannot be accepted as the cause of most food-poisoning outbreaks then what is the cause? This question can best be answered by a review of the development of the modern conception of the cause and nature of food poisoning. While the ptomaine theory still enjoyed wide acceptance, there grew up with it another conception based on the assumption that the food before eating became contaminated with bacteria capable of producing poisonous substances, known as toxins. Before proceeding further, a word about bacteria in general might not be out of place. The term bacteria includes all that vast group of one-celled fungi which reproduce their kind by fission, *i.e.*, by splitting. These micro-organisms, being members of the vegetable kingdom, obtain their food by absorption through the cell wall. When, therefore, a cell has grown to such a size that its surface area is no longer great enough to absorb sufficient food for the increasing bulk, the organism splits, forming two where but one grew before. Under favorable conditions it is possible for certain bacteria to produce one of their kind every twenty minutes. In the course of the metabolism of the food ingested certain groups of bacteria produce substances which are harmful to man. These poisonous substances are called toxins, and each toxin is the specific product of a definite bacterium. It might be mentioned that the bacteria capable of producing substances harmful to man are far outnumbered by those which are quite harmless.

Returning now to the original this bacteriological conception of food poisoning the first important investigation in which a causal connection was established between a definite bacterium and a case of food poisoning was carried out by Gaertner in 1888. At Frankenhausen, in Germany, a cow suffering from enteritis was killed. The flesh of the cow which appeared quite normal was consumed by several people who fell ill with the usual symptoms of food poisoning—severe abdominal pain, diarrhœa, vomiting, followed by prostration. One of those affected died. Gaertner succeeded in isolating *Bacillus enteritidis* both from the fatal case and from the organs of the cow. Since that date this bacillus, or bacilli closely related to it, have been isolated from a large number of food-poisoning outbreaks, and the responsibility of this group of organisms, known as the *Gaertner* or *Salmonella* group, for the great majority of food-poisoning outbreaks has been definitely established.

There are, of course, other causes of food poisoning beside *Gaertner* group bacilli, but these make up only a small minority. For example, cases of food poisoning known as *botulism* have been shown to have been caused by the infection of the food by *bacillus botulinus*. Sausages and canned foods—fruits, vegetables and fish—are usually the vehicles, and carelessness in preparation is usually responsible for the condition. The abnormal state of the food can be detected, however, before eating since the toxin produced by *B. botuliuns* imparts to the food a distinctly rancid odor and taste. Moreover, thorough cooking effectively destroys the toxin. *Botulism* is comparatively rare in this country except on the Pacific coast, accounting for only a small percentage of the food-poisoning outbreaks. Food-poisoning outbreaks resulting from the pres-

ence of poisonous chemical substances in the food, whether introduced unintentionally in the process of manufacture or intentionally for the purpose of preserving or coloring the food, are comparatively infrequent and will not be considered here. It can be said, therefore, that bacterial infection by members of the *Gaertner* group of bacteria can be accepted as the cause of the great majority of food-poisoning outbreaks.

One is naturally curious to know the kinds of food which most commonly act as vehicles of infection and the way in which they become contaminated. A study which Dr. Savage made of 112 outbreaks, occurring in Great Britain between 1880 and 1918 seems to place the greatest responsibility on flesh foods. In 21 cases the vehicle was a non-flesh food: Milk 9, cream 1, ice cream 6, potatoes 2, pineapple jelly 1, canned peaches 1, rice cooked in fat 1. The remaining 90 cases were caused by the consumption of flesh food: 37 by meat pies and potted meats made from beef or pork, 27 by unprepared meats such as pork, beef and ham, 19 by canned meat and fish, 2 by sausages, 1 by pickled meat, 4 by internal organs. It is interesting to note that the flesh of the sheep is almost never the vehicle of infection, probably because sheep are so little subject to diseases caused by bacilli of the *Gaertner* group. The general conclusion, then, seems to be that, in the great majority of these outbreaks, prepared meat foods, principally the flesh of the pig, the cow, or the ox, are the vehicles of infection. This is not difficult to understand when we consider that prepared meat foods contain large quantities of jelly, which is an admirable nutrient material for bacteria, in fact is used by the bacteriologist in his laboratory for the artificial cultivation of bacteria.

The question naturally presents itself: How then do these foods become contaminated with the bacillus whose toxin is the direct cause of most food-poisoning outbreaks? In a certain number of cases the source is straightforward, the vehicle being meat or milk derived from an animal suffering from a disease caused by one or another of the members of the *Gaertner* group. In other cases the most probable source of infection seems to be animals or insects which have the opportunity of contaminating human food. In support of this contention it may be mentioned that Dr. Milton J. Rosenau, professor of preventive medicine at Howard Medical School, at a conference of State Health Officers held at Saratoga Springs, N. Y., in November, 1920, asserted that, after three years of experimentation at Boston it had been found that ptomaine poisoning as such does not exist, but that food poisoning in the modern sense of the word is due chiefly to infection of food by disease carriers. It has been found that rats and mice are susceptible to diseases caused by bacilli of the *Gaertner* group—particularly worthy of mention is mouse typhoid, which is caused by a germ known as *Bacillus typhi murium*. This bacillus, which is pathogenic to man, is often harbored in the animal intestine for long periods after the animal has recovered from the disease. During this period, in which the animal is acting as a carrier of the disease, it has ample opportunity of infecting human food with its excreta. Moreover, there are on the market and in wide use rat and mouse exterminators which consist of bacteria belonging in the *Gaertner* group. It is true that these viruses, as sold, are not pathogenic to man, but there is some foundation for the belief that they may become pathogenic to man after repeated passages through rats or mice. There is, besides, the additional fact in support of the carrier idea, that flies infected with *Bacillus enteritidis* carry it in their crops for seven days at least, during which time they have many opportunities of transmitting the bacteria to food intended for human consumption.

There only remains in conclusion to outline a few of the means which may be employed to combat the bacterial infection of food and food-poisoning outbreaks resulting from it. In the first place, the medical profession should take a greater interest in this subject and discard, once and for all, the discredited ptomaine theory. In the second place, great care should be taken to locate food preparing plants outside the slaughter house and at a considerable distance from it. Furthermore, a high standard of cleanliness should be enforced wherever prepared meat foods are made, since these lend themsleves most readily as vehicles of infection. In this connection it would be well to obtain more exact knowledge as to the extent to which rat and mouse viruses may be converted into strains virulent to man, and to regulate their distribution. Finally the classic warning, of course, remains unchanged: "Swat the fly."

WHY BRANCHES SPREAD IN DIFFERENT DIRECTIONS

AT a recent session of the French Academy of Sciences, Oct. 18, 1920, a note was offered by the botanist, M. H. Ricôme, concerning the phenomenon of the spread of the branches of trees and plants in various directions. The author remarks that geotropism results from modifications in the growth determined by the force of gravity. It would appear that an organ possessing radiate symmetry could have no other direction than a vertical one from the force of gravity alone, yet, as we know, branches orient themselves in every direction. This geotropism is explained by M. Ricôme as being the result of an inequality in the growth of the cells. It would appear that any such inequality, no matter how slight it may be, ought to cause the growth to occur in a curved line, but branches grow in straight lines.

The orientation of branches is evidently affected, however, by the amount of water at their disposition. In any system of branches the higher the branch the more difficult the ascension of the water to it. But the higher the location of the branches the less the effect of gravity upon them, since the amount of water obtainable is more scantily distributed. However, if the axis be cut the branches will tend to erect themselves in a greater or less degree; if they be detached from the parent plant and their base be immersed in water they will assume a vertical direction. It is obvious, therefore, that they all possess the same property that the stalk has of an ascending vertical geotropism. But this property is unable to manifest itself while they are still growing on the parent stem, by reason of the fact that they cannot obtain the necessary quantity of water.

The influence exerted by the quantity of water is thus explained by M. Ricôme: The two halves of a stalk which is split lengthwise will curve abruptly toward the outside by reason of the unequal tension exerted upon the tissues—this is what is known as the *force of tension*. In each section of the curvature and at each point of the curve (ignoring the influence of neighboring incisions) the orientation forms a resultant between two forces of tension, which are opposite and which are unequally modified by the force of gravity.

The amount of turgescence depends upon the quantity of water contained in the cell. If the quantity of water be sufficient, the branch will erect itself under the continuous action of gravity until it assumes a vertical direction.

But if the quantity of water is merely sufficient to fill the cell it is retained therein by osmosis, by the elasticity of the membranes which imposes upon the cell a definite form which is capable but of slight modification, by capillary phenomena, and by the cohesion of the water. Gravity will not dispose of any quantity of water which can be distributed unequally. The organ is not affected by the gravity and takes the direction indicated by its mode of insertion upon the stalk, or the direction which is given to it artificially.

If the quantity of water at disposal for the unequal distribution is limited, the action of the gravity will cease as soon as the said distribution is accomplished. At this moment each of the two forces of tension has a value proper to itself, whereby there results a given direction of growth—this is the direction which the branch takes and to which it inevitably returns if its position be changed, since this is the position of equilibrium of its growth under the given condition.

Grafting and Evolution

Is the Success of Grafting a Criterion of the Relative Parentage of the Species?

By Lucien Daniel

Professor of Agricultural Botany at the University of Rennes (France)

THE Ancients maintained that it was possible to graft to each other two vegetable plants very dissimilar in character. The Moderns treated these affirmations as legends and thought they could show that grafting is only possible between species of one order or between species of different orders but belongisg to one family. Now the Ancients made use of both Siamese or parabiose grafting (Fig. 1) which consists of a simple fusion of tisues, and ordinary or olobiose grafting (Fig. 2) which determines a mutual parasitism more or less complete in the grafted plants in addition to the preliminary fusion of the tissues.

We can understand that success with these two types of symbiosis is not obtained with equal facility and that the manner in which the physiological functions of each conjoint are put into practice is by the no means the same in the two cases. It has been shown to-day, experimentally, that it is possible to obtain parabioses between plants very differently classified, such as the cabbage and the tomato, for example, but such anatomical combinations cannot be changed into ordinary grafts without causing the death of at least one of the grafted plants. It follows from this that the Ancients and the Moderns were right according to their points of view. They made a mistake in not thoroughly defining their subject and their disagreement comes from the fact that they gave the same name to combinations very different in nature.

FIG. 1. PARABIOSI OR SIAMESE GRAFTING OF TOMATO AND GILIA (*POLÉMONIACEÆ*)

FIG. 2. OLOBIOSIAN GRAFT OF STEIRA PURPUREA AND XANTHIUM

When it is a question of ordinary grafts, almost exclusively employed in every-day practice, their success has almost always been confined to the family to which they belong, and often, in the majority of cases indeed, successful results have only been obtained between species of the same class. It is this which led de Candolle to consider successful grafting as the true criterion of the relative parentage of groups and species and to recommend the use of grafting as a means of solving the much disputed question of classification. This was to subordinate the reproductive characteristics, until then considered as dominant, to the anatomical and physiological characteristics, to which the naturalists generally attach very little importance because they vary so readily under the influence of changes of surroundings.

Now this criterion has not the importance thus attributed to it and experiments have proved it clearly. One single fact thoroughly proved in actual practice would suffice to show it.

The pear-tree is easily grafted on the quince-tree but the quince-tree cannot be grafted on the pear-tree. In these two types of grafting the parentage of the species has remained unchanged. This example is not unique. There are other ligneous and herbaceous plants, the inverse graftings of which do not succeed with equal facility.

Besides it is sufficient to try a grafting of two species more or less separated and taken from classes of different groups belonging to the family, in order to show that the success of the operation has no close connection with the parentage of the species. Although we are unable to state the exact cause, there are in one family and sometimes in one class, convenient species which graft easily, and other species more independent which will accept a dual life with difficulty, and which die rather than enter into contact with a strange plant.

Among the genus *Solanum* the species which lends itself most readily to symbiosis is the tomato. It grafts not only with species of the genus *Solanum* but also with the *Atropa, Physalis, Nicotiana, Nierembergia, Petunia, Datura, Lycium* etc.

FIG. 3. GRAFTING OF *PHYSALIS FRANCHETI* ON *SOLANUM MELONGENA* (EGGPLANT)

Two fruits of the eggplant can be seen on the twig left on the graft-supporter. The graft has many characteristic fruits

In other words it grafts with herbaceous or frutescent plants, annual or perennial, with cycles of development very different from its own. The case is almost identical with tobacco and eggplant, which allow their graftings to reach normal height (Fig. 3). However, certain species belonging to the Cestrum and Fabiana classes refuse to live in common with the tomato. Others, however, produce very antagonistic associations, growing with difficulty and destined to a premature death. This is the case of pimento whether it serves as subject plant or as a graft. It is, however, with the tomato that

it succeeds the best (Fig. 4) but the latter yields no fruit even in the case of the most successful graftings.

The thorn-apple and the deadly night-shade are not so exacting as the pimento, but they are capricious at times. Grafted on the datura the tomato grows splendidly. The deadly night-shade grafted on the datura under the same conditions develops poorly and produces plants more or less weak according to the specimens taken (Fig. 5).

It is often the case also with the potato, which, in certain cases, is reduced to a tubercule which caps the plant in a very curious manner. The inverse grafting of the datura on the potato succeeds better as a rule, and the plants form a varying number of tubercules. However, the tomato, the potato, and the deadly night-shade are three species of the genus *Solanum*, closely related which ought to take with equal facility on the datura.

In the family of compound plants, anomalies still more pronounced and still more curious are to be found. We know that the *Xanthium Strumarium* belong to the Ambrosiaceæ related to the compound plants. But certain botanists have called it Urticacean, and others have placed it in the category of the Heliantheæ and consequently in the compound plants. It was therefore a case in which to apply the principle of the botanist de Candolle to this much disputed phenomenon. Now it happens that *Xanthium* like the tomato, is a plant which lends itself easily to grafting and unites with plants very different in nature. For example it can be grafted on the *Vernonia praealta*, and the *Stockesia cyanea* which are *Vernonieae*, with the *Stevia purpurea* which is a *Eupatoriea;* with the *Helianthus*, *Cosmidium*, *Cosmos*, *Ximenesia*, and *Bidens* which are Heliantheae; with the *Artemisia camphorata* which is an *Artemisieae*, etc. In which of these categories therefore are we to place it? This is not all. In one single group, that of the Heliantheae for example, it is far from succeeding with equal facility on species belonging to neighboring classes and for this there is no apparent reason.

Thus the *Heliantheii* grafted on *Xanthium* hardly grow at all and bear no flowers. The *Tagetes* and the *Madaria* remain stunted but produce flowers and bear fruit (Fig. 6); the *Cosmos* develop fairly well although they remain smaller; the *Bidens* on the contrary become very rich (Fig. 7).

These examples show that even when ordinary grafting only is used, successful grafts taken as a criterion of parentage would result in very strange groupings contradicting the best suppositions already established by means of the natural method. Among the plants the anatomical and physiological parentage which determines the success of grafting does not always coincide with the parentage of reproductive organisms which forms the basis of our classifications at the present day.

During the last few years much stress has been laid on the principle outlined by de Candolle, in order to establish the parentage of some of the higher animals with man. The excellent research work of Dr. Carrel is known in connection with animal grafting, and we know also that he succeeded in placing in the human body organisms belonging to the moneky, the dog, the sheep and the cow. The parts taken from the monkey did not take nearly so well as those taken from the other three animals and as a result of which the following conclusions were drawn:

"The most recent scientific discoveries tend to reject Darwin's theory rather than to confirm it. For many years many men with great scientific knowledge have declared that the analogy existing between the human structure and that of the monkey, proved directly that the former must be a more advanced variety of the family to which both belong. According to their theory, generation succeeding generation, brings about in the anatomy of the monkey modifications and improvements which bring the quadrumane gradually nearer and nearer the human type.

But the science of physiology and anthropology takes up a different point of view. It considers the formation of different tissues and glands, their resemblance, their natural longevity,

FIG. 4. TOMATO GRAFTING (*SOLANUM LYCOPERSICUM*) ON PIMENTO (*CAPSICUM ANNUM*)
The graft bears one fruit and has not branched out

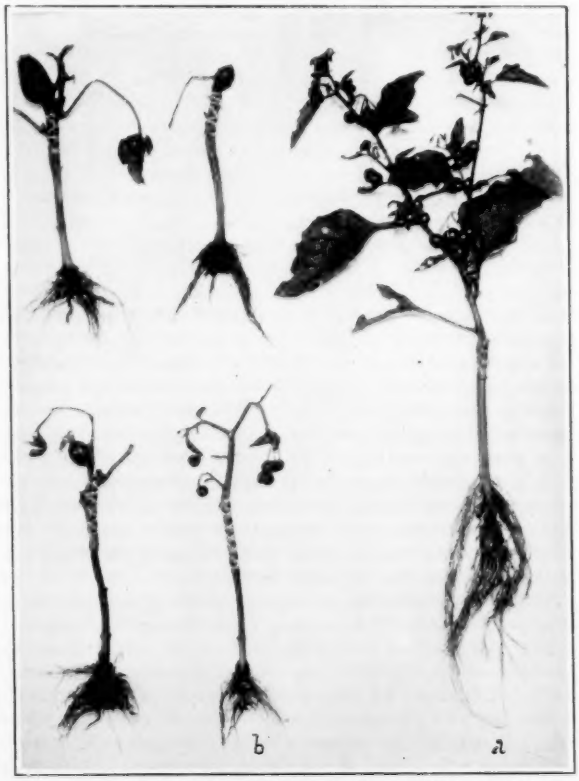


FIG. 5. GRAFTING OF DEADLY NIGHT-SHADE (*SOLANUM NIGRUM*) ON PIMENTO
Potato graftings (*Solanum tuberosum*) on Pimento are shown at left

FIG. 6. GRAFTING OF *TAGETES* ON XANTHIUM

FIG. 7. GRAFTING OF *BIDENS CERNUA* ON XANTHIUM STRUMARIUM SHOWING A VERY RICH AND FULL DEVELOPMENT

FIG. 8. POTATO GRAFTED ON TOMATO, BEARING TUBERS ABOVE GROUND

their aptitude for growth, when transformed to another being, as the fundamental basis of all comparative study. Now this method once adopted as the true criterion of reasoned study, it is absolutely impossible for man to have ever had for this prehistoric ancestor a monkey of any kind."

I have not, in this article, to give a decision for or against such and such hypothesis concerning the descent of the human race. But the results which have just been indicated concerning the Parabioses (anatomical grafts) and ordinary grafts (anatomical and physiological grafts) show that the criterion fixed cannot be applied to vegetable plants. It is quite possible that the same thing may be said in connection with animals. However interesting the graftings of Dr. Carrel may be, however strange certain vegetable fusions may be, we must not give them a philosophical importance or bearing which they do not possess. Scientifically they leave untouched the anxious problems of the origin and the evolution of the species.

A NEW METHOD FOR GROWING PLANTS

IN the *American Journal of Botany* Dr. J. M. Brannon describes an interesting new method for growing plants.

In growing plants under sterile conditions, says the author, investigators have employed either agar cultures or some other substratum of solid or semi-solid character placed in culture tubes, or else they have used water or soil cultures. In the water or soil cultures the roots only are maintained sterile, leaves and stems being exposed to the atmosphere.

In the course of investigations on the organic nutrition of plants, the author noted at various times that seeds would germinate and seedlings would grow even when entirely immersed in a liquid medium. As a result it was decided to test the possibility of using such liquid cultures for the investigations. Striking successes were obtained, and the superiority of this method for growing plants in the dark over the agar method or the water culture methods was at once apparent.

In a flask or culture tube, the size depending upon the plants to be grown and upon the duration of the experiment, is placed the culture solution. The depth of the solution should not exceed six centimeters. The vessels are plugged with cotton and then autoclaved. The seeds to be sown are then sterilized and the desired number sown in the culture solution. In the work reported by the author the seeds were sterilized by the calcium hypochlorite method of Wilson. This method of growing plants has been used with flax, alfalfa, corn, pea, and timothy. These were all grown in the dark.

The special advantage of this method is in the fact that the plants used will live and grow for a much longer period of time than by the other methods. It would seem, in the case of plants grown in the dark, that the sugars are either too slowly absorbed by the roots or that conduction of the sugars is too slow to satisfy the needs of the plant.

Another advantage over the agar method is the greater ease of analyzing the solution. In the agar method the agar must first be removed before the sugar determination can be made. Absorption phenomena inadvertently play a part in the precipitation of agar, thus another source of error is introduced.

THE LIFE OF THE CELL

THE capacity for functioning possessed by the body depends upon the delivery of nutritive substances to the cells, since it is these which not only build up the organs but, moreover, are intimately connected with the nervous impulse which is twofold in each cell—exciting and inhibiting. In each organ and demonstrably in each cell a double system of nerve fibers leads to the nucleus (the nucleim body, chromosome) the one springs from the original organizer of all living substance, namely, the sympathetic nerve system—*Nervus sympathecus.*

A recent German writer, Carl Schleich, calls this great sympathetic nerve, on account of its mysterious and unknown origin in the rhythm of the universe "The Marconi plate of the Universe" and he expresses the concept that all so-called intuitive impulses inexplicable antipathies and sympathies, forebodings, ideas of inventors, mediumistic and super-intellectual capacities, etc., are connected with the metaphysical functioning of the *nervus sympathecus.*

The other guiding system directing the inner activities of the cell springs from fibers coming from the later developed central nervous system (brain and spinal column). It controls the capacity for industrial orientation—the expression of the personal will, while the *Sympathicus* is the bearer of the race-will. The central nerve system is the forward, striving, exciting the rouser of the cell's activities.

It represents the dynamics of the double nervous system upon which the hormones secreted by the internal secretion glands make their presence felt. The shriveling or the reconstruction of cells, their atrophy or their overgrowth (hyperplasia) are the result of the interplay of these two cell registers.

Thus we can readily understand how the hormones both excite and inhibit. The hormones of the puberty gland stimulated by Steinach's process causes the entire system of cells to become once more capable of regeneration. . . . And so he attains artificial adolescence.

New Facts About Red Corpuscles*

Studying the Blood Cells by Methods Suggested by Colloid Research

By Dr. Bechold

"THE living organism is a complicated piece of watch work." This often heard comparison does not quite hit the mark, for when but one tooth of a gear wheel is broken out of a watch, the latter either stops or its movement is disordered. But from even the highest organism, that of man himself, very considerable portions can be abstracted without very gravely affecting the organism. Thus, both legs, one of the kidneys, or a portion of the intestines can be taken away without too serious results. There is, to be sure, a difference in vital importance of the various tissues of the body. The muscle of the heart is more important than that of the arm and certain portions of the brain are more important than the peripheral nerves. From this point of view the *blood* must be ranked as one of the most vitally important organs, for if a considerable portion of this fluid be lost, life itself ceases. And in the blood it is the corpuscles which play the most important rôle.

We shall here confine ourselves to a discussion of the red blood corpuscles or *erythrocytes*, as they are called from the Greek words *erythros* for red and *kytos* for cell. Since the white blood corpuscles or *leucocytes* (*leukos* is the Greek for white) do not enter into the problems with which we expect to deal in this article, we shall omit further mention of them. In human blood the red blood corpuscles have an average diameter of about 0.007 mm. and in a healthy man there are about 5 millions per cubic millimeter while in that of a woman there are about 4.5 millions per cu. mm.

The knowledge and the study of the blood and especially of its corpuscles is of the greatest significance in medicine. A physician estimates the number of the red blood corpuscles in the blood of a patient and also studies their tint, concluding that anaemia is present if they are much below par either in color or number.

Blood is a yellow liquid within which float the disc-like red corpuscles which lend it their hue. Besides the color and the number of these bodies their form offers valuable information, especially in a group of grave diseases which include leucamia, many infectious diseases, and cases of chronic poisoning. Hitherto the study of the blood corpuscles has been attempted by the microscope alone. The expert haemotologist placed a drop of blood upon a glass slide and observed it through the lens of his microscope, which revealed that it contained a number of pale yellow discs, to form a judgment of whose condition required both a keen and a well-skilled eye. The corpuscles are much more readily observed, however, if they be colored artificially. The method of doing this medical science owes to Paul Ehrlich.

The simplest animal cell. The red blood corpuscle is regarded as the simplest form of cell present in the body of an animal. For purposes of study it possesses the advantages over other cells, that it can be conveniently taken from the body and subjected to observation and experiment so as to find out the nature of its behavior under the most various influences. The information thus gained from the study of red blood corpuscles is considered applicable—whether the opinion be correct or not does not matter here—to the other cells and unions of cells or tissues. On this account there is no part of the body that has been more carefully studied than the red blood corpuscles, whose conduct forms the basis of what we know respecting what happens in the tissues of men and animals under normal and under diseased conditions, under the influence of poisons and of medicines, and under the conditions of self defence against injuries, *i. e.*, of immunity.

One might well think from this recital that we now possess extremely exact knowledge as to the structure, properties, and behavior of the red blood corpuscles, but this is by no means the case. We know that they contain about 62 per cent. of water and that in the water about 32 per cent haemoglobin is dissolved (estimated from the total corpuscle).

Haemoglobin. Haemoglobin is the red coloring matter which takes up the oxygen in the lungs. The blood corpuscles also contain from 0.4 to 0.7 per cent of fatty constituents, known as lipoids; these are composed of two kinds of materials: A wax-like body called a cholesterin, and a fat called lecithin which swells when placed in water, forming an emulsion with the latter; lecithin contains phosphoric acid. The blood corpuscle also contains a number of salts which are never lacking in the remainder of the organism; these include sodium chloride, potassium chloride, calcium compounds, etc.

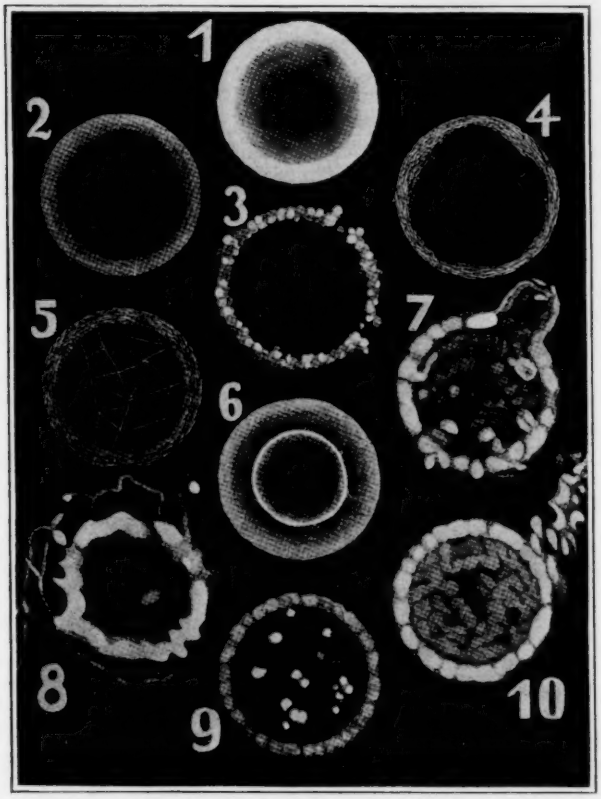
When the red corpuscles are separated from the rest of the blood, the plasma, they can be preserved a longer time if they are placed in a solution of salt and water containing the salts in the same degree of concentration in which they are present in the blood. This solution is called Rinerg's solution. For most purposes, however, what is known as physiologic salt solution, which consists of water containing 0.85 per cent of ordinary cooking salt will suffice. The floating mass is brilliantly red and non-transparent (opaque in color). If it be diluted with pure water it may be seen under the microscope how the separate cells swell, and if the solution be still further thinned there finally comes a moment when they entirely disappear. This can be recognized as taking place in a test tube by the fact that the floating blood begins to become more transparent until, finally, the tube contains an entirely transparent fluid of a beautiful shade of red. The blood has become a "lac dye." This process is termed getting a "blood solution" or *haemolysis*. As we shall see later this expression is not quite correct, for we never obtain a true solution in the chemical sense of the word, as we do for instance when we dissolve sulphate of copper in water. Another experiment also shows that not all the elements have gone into the solution. If such a "blood solution" be briskly centrifugated so as to make it fly out of the tube, there will remain at the bottom of the latter bits of white film. When haemolysis takes place under the miscroscope to all appearance everything vanishes; by making use of an artificial coloring matter, however, it can be demonstrated that a very delicate film remains behind which is identical with the bits of film obtained in the tube. These very delicate films or skins are known as "shadows" or *stromata*.

These observations, together with the aspect of the blood corpuscle under the microscope, have led to various attempts at the formation of a plausible concept with regard to the structure of such a blood cell. Hitherto opinions have differed widely in respect to this matter. It formerly was supposed that the blood cell was a sort of bubble with a fluid content (haemoglobin solution) and surrounded by an envelop of albuminous matter. These enclosing envelops or skins were supposed to be the source of the stromata mentioned above. Somewhat later the opinion prevailed among some students that the stromata constitute a sort of sponge in which the haemoglobin solution is absorbed (either with or without a protecting envelop). The process of haemolysis presents peculiar difficulties to investigate. The explanation which found favor at any given time reflects, indeed, the current physical and chemical theories in their application to questions of biology and physiology.

When the doctrine of *osmotic pressure* entered upon its vic-

*Translated for the *Scientific American Monthly* from *Die Umschau* (*Frankfurt*), for May 28, 1921.

torious course some thirty years ago, it was hailed by those who believed they found in its application to the processes of haemolysis a peculiarly convincing example in the domain of biology. If a solution of sugar be placed in an unglazed porous clay cell, whose pores are of such a size that water can pass through them, but not sugar, then the following phenomena are observed: If the cell be immersed in water, water will pass through the walls to the inside so that the solution of sugar will be diluted. If, on the other hand, the cell be placed in a more highly concentrated solution of sugar, then water will pass from the inside to the outside of the clay wall, so that the solution in the cell will become more concentrated.



RED BLOOD CORPUSCLE AND ITS SOLUTION OR HAEMOLYSIS UNDER THE ULTRA-MICROSCOPE

1. Intact red blood corpuscle. 2. Stroma. 3. Division of the periphery into grains (cholesterin is brightly luminous and lecithin faintly so). 4. Remainder of the stroma after removal of the lipoids. 5. Diagram of the stroma. 6. Formation of a concentric ring at the beginning of the haemolysis. 7. Beginning of haemolysis in sublimate (1/20,000 sol.); note blister-like projections. 8. Tube-like projections made under the influence of sublimate (1/20,000 sol.), 9. Final stage of haemolysis by water. In the inside are dancing balls of cholesterin. 10. Hardened corpuscles with a "ball of wool" structure and escape of clotted haemoglobin under influence of sublimate (1/2,400 sol.).

This exchange of water between the two solutions always takes place except when the osmotic pressure on both sides of the clay wall is the same, *i.e.*, when there is a like concentration both within the cell and outside of it. If the wall used in the experiment is not rigid, as it is in the case of a clay cell, then the inflow and outflow of the water can be recognized by the corresponding swelling or shrinking of the cell. This process can be observed admirably in blood cells. In solutions which are more dilute than physiological salt solutions, *i.e.*, in *hypotonic* solutions, the blood corpuscles swell, but if they are placed in *hypertonic* solutions, *i.e.*, in those which are more concentrated than physiological salt solutions they shrivel and assume peculiar jagged forms which are called "thorn apple" forms (from the fruit of the stramonium). From these phenomena the conclusion was drawn that the blood corpuscle possesses a "semi-permeable" skin like the clay cell described above, *i.e.*, a skin or envelope permeable to water but not to the substances dissolved therein; it was supposed that this envelop was composed of albumenoid bodies: And furthermore, that when the pressure became too great, *e.g.*, in pure water, the corpuscle burst and allowed the haemoglobin solution to flow out. But in spite of the coincidences in the phenomena observed there are some contradictions which make it impossible to accept such an explanation. Chief among these is the fact discovered that this envelop or cell wall is permeable to many dissolved substances; but for the processes of swelling and shrinking to take place a condition of semi-permeability, *i.e.*, an absolute exclusion of everything except water, is a requisite condition.

A theory has been formulated by Overton and Hans H. Meyer, according to which each cell is supposed to be surrounded by a lipoid membrane, that is, by an envelop of a fatty nature. This would allow only those substances which are soluble in lipoids to penetrate the cell. The main object of these investigators was to find an explanation for the phenomena of narcosis. They were able to prove that narcotic substances, such as ether, chloroform, chloral, etc., exert a narcotic effect in direct proportion to their solubility of fats. The thought readily occurred that this theory might be extended so as to apply to other cells, such as blood cells; it is a fact that fat dissolving substances, *e.g.*, certain dye stuffs, are capable of penetrating them. This suggested the idea that the envelop of the blood corpuscle contains lipoids. Since, as we have said above, red blood corpuscles are known to have a content of from 0.4 to 0.7 per cent of lipoids, this theory appeared to have much in its favor. However, it is contradicted by the fact that many substances which are soluble in water but *not* in lipoids are capable of penetrating blood cells. Nathanson sought to find a way out of this dilemma by the concept that each cell envelop may have a sort of mosaic structure, being composed partly of lipoids, partly of cholesterin (which is incapable of swelling) and partly of a semi-permeable albumenoid material. Such a cell envelop was supposed to answer the requirements insisted upon by Höber to the effect that the cell must possess some sort of contrivance enabling it to regulate the "import" and "export," so to speak, of building materials and waste matter. The mosaic structure suggested by Nathanson was a hypothesis which other investigators accepted with more or less modification, but for which no convincing proof is given.

This was the position of the question when the present writer, a professor in the Institute for Colloid Research at Frankfort, a.m., together with a number of distinguished colleagues, Messrs. K. Hattery, W. Kraus, S. Neuschloss, and E. Salén took up the question afresh.[1]

EXAMINING BLOOD CORPUSCLES BY THE ULTRA MICROSCOPE

The ultra microscope in combination with the arc light offers possibilities of detecting details far beyond the power of the ordinary microscope. Furthermore, one can dispense with the dyes necessary in the ordinary microscope, whose use, moreover, always involves a chance of error. Then, too, the methods employed in the study of colloids offer new paths for approaching the present problem.[2]

[1]Bechhold. Structure of the red blood corpuscles and haemolysis (in German). *Munch. Med. Wochenschrift*, 1921, No. 5.

[2]Vide also Raehlmann (*Deutsch Med. Wochenschrift*, 1904, No. 29; Loewit). *Ziegler's Beitr*, Vol. 42 (1908), p. 559, etc., and especially A. Dietrich (*Arb. d. Path. Inst. z. Tübingen*, Vol. 6 (1908), p. 375, etc.; and Proceedings of the German Pathological Society, all of which articles have thrown much light on the obscure field of the red corpuscles. The latter also holds because of these experiments that the red corpuscle consists of a bubble-like envelop with a homogeneous content of haemoglobin. The definite proof thereof, namely, "the dancing spheres" is lacking. The explanation of the structure of the envelop and of the process of haemolysis was first made possible by the methods of colloid research applied by ourselves to this subject.

To begin with, E. Salén took up the problem as to the structure of the stromata.[3] In the ultra microscope an intact blood corpuscle has the aspect seen in Fig. 1 (all the figures, shown are much conventionalized); after the conclusion of the process of haemolysis the stromata remain and are recognizable as a faintly shining ring (Fig. 2). The process of haemolysis takes place in such a manner that according to the conditions of the experiment the shining edge of the disc is dissolved into grains as shown in (Fig. 3) or else a ring separates from the periphery and contracts concentrically (Fig. 6) until it has formed one or more spheres (Fig. 9) which dance hither and thither in the interior of the disc.

In the meantime there was a short period during which the blood corpuscle was extinguished, while Fig. 1 changed into Fig. 2. Obviously this is the instant during which the haemoglobin solution flows inside the cell towards the outside.

Salén then decomposed the remaining stromata with different solvents successively. From these investigations it was learned that the stromata consist of an extremely delicate, readily stretched framework not unlike a cobweb in appearance (Fig. 5); the edge of this framework is stiffened by fibrillae on the periphery (Fig. 4). The spaces between these tiny fibers bound together like a cobweb are plainly filled with lipoids. It is this structure which somewhat resembles that of a balloon net which makes it possible for the blood cell to swell when placed in a hypertonic solution; this also explains the formation of the so-called "thorn apple forms" which occur when the blood corpuscle shrivels upon being placed in more highly concentrated solutions.

The possibility considered above of an inside framework on scaffolding, is weakened by the fact that in many cases of haemolysis the dancing balls make their appearance in the interior (Bechhold and Kraus).[4] This is naturally not to be reconciled with the idea of an inner framework.[5]

The *part played by the lipoids*, the cholesterin and the lecithin, in the blood corpuscle was peculiarly obscure. As we have said, Salén's experiment showed plainly that these substances fill the meshes of the framework. As we can see clearly, even in Fig. 2 the stromata are almost black, only the edge gleaming with a dark glow. Lecithin, indeed, is but faintly luminous in the ultra-microscope, but cholesterin, on the other hand, is distinguished by its intense luminosity. When we recall that cholesterin is *always* found in company with lecithin in the blood corpuscle, we see why it was so hard to understand the reason for the darkness displayed in the ultra-microscope.

But a highly surprising explanation of this circumstance was yielded by the experiments by Hattory[6]: *in the swollen lecithin the cholesterin forms a colloidal solution*, and as such it presents a dark aspect in the ultra-microscope; not until there is a *separation* of the two so that the cholesterin stands apart from the lecithin does the former appear in the form of brightly shining, dancing spheres or balls (Figs. 3 and 9), while the latter forms a droplet shining with the faint gleam peculiar to itself. Further researches made by Bechhold and Neuschloss[7] next showed that a swollen lecithin possesses an uncommonly low surface tension, that it has a tendency to spread itself out upon surfaces, and that as a result of this property the meshes of the protein framework inevitably fill up in the same manner that the meshes of wire gauze become filled by soap bubble films.

Here it seems probable that we have a definite explanation of a structure of the blood corpuscles, which may be described as follows: It consists of a net-like swollen framework of protein, whose meshes are filled by the lipoids, *i.e.*, by a colloidal solution of cholesterin in swollen lecithin. This bubble-like envelope encloses the salt containing solution of the blood pigment, the haemoglobin.

But these investigations also yielded an explanation of the nature of *haemolysis;* the colloidal solution of cholesterin in swollen lecithin remains unaltered when placed in physiological solution. If, however, they be placed in water or in hypertonic salt solutions (*i.e.*, those of lower concentrations) then a separation of the cholesterin and the lecithin takes place. Hence we see that the normal state of the envelop of the blood corpuscle is conditioned by the equilibrium that obtains between the swollen framework of protein and the colloidal of cholesterin in lecithin. If one of the three components be altered or abstracted from the union, then the envelop becomes permeable to the content of liquid haemoglobin, whereupon haemolysis occurs. The case is exactly similar to that which we find in ceramic masses: The clay vessel and the glaze thereupon must have the same coefficient of expansion, since otherwise the glaze cracks off and the vessel ceases to be water-tight.

When we test the various substances which exert a haemolytic effect we find a confirmation of the above statements. It is a well known fact that blood corpuscles will dissolve when either heated or frozen; the reason for this is that these physical factors also occasion an unequal alteration of the condition of swelling or expansion of the lipoid mixtures and of the protein framework. Concentrated solution of the neutral salts (such as table salt, sulphate of ammonia, etc.) as well as dilute solutions of the salts of heavy metals, precipitate albumen and, therefore, cause a shrinking in the expanded framework of protein and thus bring about haemolysis, as we have long known. The solutions of heavy metals, such for example, as sublimate, must, therefore, be extremely dilute, otherwise they will precipitate the haemoglobin also in the blood corpuscle and the latter will, apparently, remain unaltered. Under the ultra-microscope the fact that this precipitation has taken place is recognized by the structure, which resembles a piece of knitting as shown in Fig. 10, in which figure we also see some of the haemoglobin appear which, however, is immediately clotted. Previous stages (in more dilute solutions of sublimate) are seen in Figs. 7 and 8 where we are able to recognize the alteration which has taken place, especially of the outer envelop: blister-like projections and the tube-like so-called "myelin forms."

Solutions which dissolve fat, most of which also coagulate albumen and which, therefore, have the effect of separating the lipoids from the framework of the albumen, must necessarily produce haemolysis and this is also proved by tests made with ether, alcohol, cholesterin acid salts and chloroform. There are not only reagents which precipitate albumen but others which precipitate the swollen lecithin; these include, for example, saponin, the well known substitute for soap made from the so-called soap bark or quillaya bark and these also occasion haemolysis.

These experiments show plainly that it is not the alteration of the osmotic pressure, as such, which is the controlling factor in the process of haemolysis, as has so long been thought. Rather has it been demonstrated that haemolysis is the result of the separation from each other of the three constituents which are united to form the envelop of the corpuscle, namely, the protein framework, the lecithin and the cholesterin.

Every influence which affects unevenly the condition of expansion of the protein framework or of the lecithin, must result in haemolysis, as likewise any sort of attack which alters the state in which the cholesterin is dissolved in the lecithin.

FINAL REMARKS

It is exceedingly probable that the conditions which we have thus found to obtain in the case of the blood corpuscle are also effective to a greater or less extent in that of other cells, such as those of bacteria, plant cells, and the cells of organic tissues.

[3] E. Salén. *Biochem's Zts.* 110 (1920), p. 176.

[4] Idem, 109 (1920), p. 226.

[5] Now that the nature of the constituent non-soluble in water is known I propose to call it merely by the name of *envelop* or *membrane*, instead of by the earlier names of *stromata, shadows, discoplasma,* or *oikoid.*

[6] *Biochem. Zts.,* 1921.

[7] *Kolloidzeitschrift,* 1921.

Gorillas, Champanzees and Orang-Utans

Some New Observations on the Characteristics and Habits of the Man-Like Apes

By May Tevis

Illustrated with photographs from the New York Zoological Society

AT the head of the animal kingdom stand the primates. Some authorities indeed consider that man himself is merely one genus of the primates. The superior members of this great class are known as the man-like apes. As we shall see they bear a close resemblance to human beings anatomically and in various other ways. Even in their mental qualities there are points of resemblance, for example, they are imitative, so much so that the very word ape has acquired a secondary use as a verb meaning to imitate; again they are intensely curious and man, as we know, is the most curious of all animals—perhaps, indeed, it is not too much to say that it is this quality of curiosity which has led him ever onward and upward along the steep paths of knowledge.

In aspect, too, the primates strongly suggest man, especially the men of the less developed races. Strange to say, however, this resemblance does not add to their beauty nor make them more attractive to man. On the contrary there is nearly always something grotesque or even repulsive in this similarity, while some specimens fill us with a sense of shuddering disgust, suggesting some hideous and devil born caricature of mankind. This likeness, by the way, is much more marked and at the same time less repellant in the young animals than in the adults. This is partly due to the fact that the ridges of the skull are not developed so as to accentuate the difference, while another is that the bodies are nearly naked of hair like that of man. Mr. Carl E. Akely, associate of the American Museum of Natural History, told the writer recently that he had seen in the London Zoo some years ago a baby gorilla which was quite startlingly human in its appearance. Paul du Chaillu even goes a step further in his famous book of travels. He states that he was greatly astonished upon capturing a female Chimpanzee with a young one clinging to her to find that the face of the latter was as white as that of a European child, although the mother's face was black. His surprise greatly amused the negroes with him and they said to him facetiously "Here is your little white friend, Chelly. When we catch a gorilla you say to us 'Look at your black friend,' now we say to you, 'Look at your white friend.' Look at your little white cousin of the forest, it has straight hair like you, too. It looks much more like you than the gorilla does like us. The gorilla may be black like us, but it hasn't got wool on its head, and the chimpanzee has a face like you and hair like you, too." Whereupon they all burst into roars of laughter. Du Chaillu accepted the joke amiably and replied, "Yes, but he has a flat nose like yours, and when he grows up his face will be black, too"—remarks which increased the general hilarity of the natives.

Probably, however, it is the intelligence of apes, large and small, and the resemblance of many of their habits to those of human beings that makes them always objects of interest and even fascination to mankind, though they are seldom either admired or loved as are dogs and horses.

The Anthropoid, or man-like apes, may be separated from the lower apes as a group, Simiæ, or as a family Simiidæ, which has the following distinctive characters:

Though tree-living creatures for the most part, these apes, when they come to the ground, move in at least a semi-erect fashion. When they put their hands upon the ground to aid in walking, they do not rest as do the lower apes upon the flat of the hand, but upon the back of the fingers. None of the anthropoids has a tail, or cheek pouches. There is commonly a laryngeal pouch which is of large size, and aids in the production of the voice which is usually very loud. The hair is rather more scanty than in the lower apes. The placenta differs in detail from that of the lower apes, and is exactly like that of man. Their arms are longer as compared to their legs than in the lower apes and they have a vermiform appendix to the cæcum. In the latter but not the former character they agree with man. The anthropoid apes are entirely Old World and dwellers in the tropics at the present time.

The Gibbons, genus *Hylobates*, stand quite at the base of the series of existing anthropoid apes. They are the smallest and the most purely tree-frequenting of all the members of that group. In the skull the chief noteworthy character as compared with the other anthropoids is the fact of the large size of the canines which are of equal or nearly equal size in the two sexes. The molars on the other hand have been particularly compared to those of man. The brain is simpler than in the higher forms. But it is not clear that this may not be a case of diminished complexity of convolution going hand in hand with smallness of size, according to the Cambridge Natural History.

Of gorillas, genus *Gorilla*, there is but one species, which must apparently and rather unfortunately be called *Gorilla gorilla*.

The external aspect of this great anthropoid is familiar from many reproductions. The male, as is usual, is larger than the female, and his characters are more pronounced.

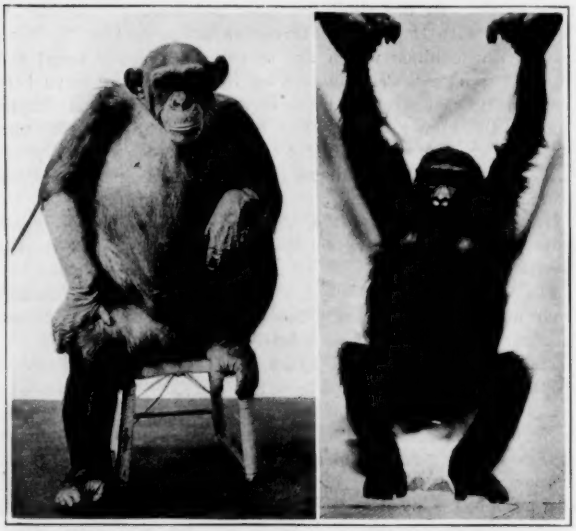
The face is naked and black, and the skin generally is deep black, even at birth. The ear is comparatively small, and lies close to the side of the head; it is altogether more human in form than that of the Chimpanzee, and this statement applies also to the rudimentary condition of the muscles of the ear which are more rudimentary than in the Chimpanzee. The nose has a clearly marked ridge in the middle and the nostrils are very wide. The hands and feet are short, thick, and broad; the fingers and toes are webbed. In the foot the heel is more apparent than in other anthropoids; it is not, however, so marked as in man. The hair upon the head forms a kind of crest which can be raised when the animal is angered. The neck is thick and short, and the beast has massive shoulders and a broad chest.

If it were not for the fewness of the Anthropoid apes and their nearness to man it is doubtful whether the gorilla would be ranked as a distinct genus (it is not so ranked by everybody), for in internal structure it is very near the Chimpanzee.

The cranial capacity of the gorilla is greater than that of the chimpanzee. It is not possible, however, to decide from this point of view whether a given skull is that of one or of the other of these apes. Some chimpanzee skulls are higher in capacity than some gorillas. But the average is undoubtedly as stated. It is to be noted that there is an inverse ratio between cranial capacity and size of plate, *i.e.*, the greater the brain the smaller the palate. This applies to man as compared with his ape-like relatives, but does not apply so accurately to the gorilla, which has a more extensive palate than the chimpanzee; its "brute development" is much greater than that of the chimpanzee. Not only is the palate larger, but the molar teeth, slightly different in form, are also larger and stronger. This is so plainly marked that "one may say almost with certainty, that any upper molar tooth over 12 mm. in length is that of a gorilla, and under

12 mm. is that of a chimpanzee." In the skeleton generally it may be said that the crests for muscular attachments upon the bones are greater in the gorilla. The nasal bones are much more like those of lower apes in their length, and they have a sharp ridge more marked than in the chimpanzee, which, however, disappears in aged animals. It is a curious fact that gorillas often have a "cleft palate," owing to the failure of the palatal part of the palatine bones to meet completely. The general conformation of the skull is less brachycephalic in the gorilla.

The limbs show a number of small differences, which are associated with a more completely arboreal life in the chimpanzee as compared with the gorilla. The latter is approaching the human way of life. In spite, however, of these differences, no hard and fast lines of divergence can be laid down between the two African Anthropoids, for it appears from the many memoirs that have been written upon both that "there is scarcely a feature in any muscle or bone found in one animal which is not also found in the other." The heel of the gorilla has already been referred to. This is, of course, associated with a plantigrade, earth-walking habits of progression.



SUZETTE, THE FAMOUS CHIMPANZEE, WHO WAS FORMERLY A VAUDEVILLE PERFORMER

YOUNG GORILLA "IN THE HANDS OF HIS FRIENDS" IN THE NEW YORK ZOOLOGICAL GARDENS

Certain of the muscles of the calf of the leg attached to the sole show a more human arrangement in the gorilla than in the chimpanzee. It is interesting to find that the muscles of the little toe are diminishing in the gorilla as in man. This is most clearly due to its habit of walking on the ground. The arm of the gorilla is less adapted to tree-traveling. Its proportions differ from those of the arm of the chimpanzee in that the fore-arm is shorter. In both animals the thumb is not of much use, and this digit is more retrograde in the gorilla, not only in proportionate length but in its muscles. The hip girdle tells the same tale. It is broader in the gorilla, and the glutaci muscles are more prominent, all these features being connected with the more erect gait.

The brain of both animals has been studied, but not from many gorillas. On the whole, the gorilla has the larger brain, but this must be discounted by the fact that it also has the larger body. It is a remarkable fact that the gorilla's liver is much more like that of the lower ape than the liver of the other anthropoids. It has, as has the chimpanzee, laryngeal sacs. The general conclusion concerning the relative position of the two African Anthropoids seems to be that the gorilla is the more primitive; and as thus it must approach more nearly to the original parent than does the chimpanzee; it may be said that it also comes rather nearer to man, since the chimpanzee has traveled away from the common stock on another line. The detailed likeness to man, however, mainly comes from a tendency to walk in the same manner.

In mental characteristics there is the widest difference between the two apes that we are considering. The chimpanzee is lively, and at least when young, teachable and tameable. The gorilla, on the other hand, is gloomy and ferocious, and quite untameable. When angry the gorilla beats its breast, a statement that was originally made, we believe, by M. du Chaillu, but which has been disputed, though it appears to be perfectly true. A young gorilla exhibited in the gardens of the London Zoo could be observed to do so. The cry of the chimpanzee is different from the "howl" of the gorilla. An immense amount has been written upon the ways of this animal in its own home, including much that is legendary. The gorilla has been said to lurk in the depths of the forest, and to stretch down a prehensile foot to grasp and strangle an unfortunate black man passing below. It is said, too, to vanquish the elephant by hitting it hard upon the trunk with a stout stick and to crumple up the barrel of a rifle with its powerful teeth.

The gorilla is limited in its distribution to the forest tract of the Gaboon. It goes about in families, with but one adult male, who later has to dispute his position as leader of the band with another male, whom he kills or drives away, or by whom he is killed or driven away..

It feeds upon the berries of various plants, and upon other vegetable food; there is apparently not so marked an inclination for animal food as is exhibited by the chimpanzee. In search of their food they wander through the forest, walking partly upon the bent hand, and progressing with a shuffling gait. It is noteworthy that the gorilla has been said to walk upon the palm of the hand and not upon the back, as is the case with the chimpanzee. It can readily assume the upright position and, in this case, balance itself largely with its arms. Professor Hartmann, however, states that the back of the hand is also used. Unlike most or many wild beasts, the gorilla exhibits no desire to run away when he views a human enemy. Dr. Savage remarks that "when the male is first seen, he gives a terrific yell, that resounds far and wide through the forest, something like kh-ah! kh-ah! prolonged and shrill. When making an attack the gorilla rises to his feet, and as a full-grown animal reaches a height of some five feet, he is a most formidable antagonist. The attack of one of these animals is said to be made with the hand, with which he strikes his adversary to the ground, and then uses the powerful canines. The beating of the breast which heralds an attack is a statement made by M. du Chaillu.

The chimpanzee, genus *Anthropopithecus* (or Troglodytes) are to be distinguished from the gorilla by the characteristics mentioned above. Briefly summed up they are mainly as follows: The ears are large, and generally stand out from the head; but there are exceptions to be noted presently. The coloring of the body is not always so deep as in the gorilla. The nasal bones are shorter. The skull as a whole is more brachycephalic, and the molar teeth are smaller. The hands and feet are much longer, the animal being more purely arboreal than the gorilla. The female chimpanzee is slightly smaller than the male, but there is less difference than in the gorilla. The animal, like the gorilla, has large air sacs.

Chimpanzees are entirely restricted to Africa, and though they appear to extend rather farther east than the gorilla, the forest-clad region of the equatorial belt is their home.

It has been mentioned in treating of the gorilla that the main feature of this animal, which affords a constant difference from the chimpanzee is its gloomy and ferocious manner. The chimpanzee, on the other hand, is lively and playful, though often maliciously so, and quite tameable, as many instances—particularly that of "Sally" of the London Zoo—show. The earliest mention of animals that are probably

chimpanzees is to be found in a work upon the Kingdom of Congo published in 1598.

The Orang-Utan, genus *Simia*, has but one definable species, viz., *S. satyrus*. The supposed species of Owen, *S. morio*, cannot be satisfactorily defined. Plenty of other specific names have also been given to what is in all probability but a single species of large anthropoid ape inhabiting the islands of Borneo and Sumatra.

The name Orang-Utan, now applied exclusively to the subject of the present description, was formerly applied also to the Chimpanzee, and to that animal, moreover, under the Latinized version of *Homo sylvestris*. The orang is a large and heavy ape with a particularly protuberant belly and a melancholy expression. The face of the old male is broadened by a kind of callous expansion of naked skin at the sides. The color of the animal is a yellow brown. The ears are particularly small and graceful and lie close to the head, which is very broad. The arms are very long, and when the animal stands they reach the ankle. It is a curious fact that the head of the thigh bone is unattached by a ligament to the socket of the pelvis in which it articulates, a state of affairs which may give the limb greater freedom in movement, but does not add to its strength.

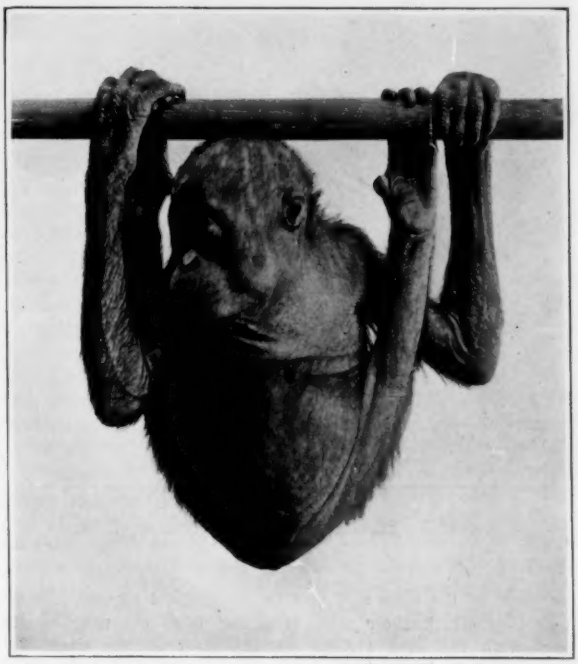
This ape inhabits flat and forest-clad ground, and lives mainly in the trees. The male leads a solitary life except at the pairing season, but the female goes about with her family. On the ground the orang walks with no great ease, and uses his arms as crutches to swing the body along. Even on trees the rate of progress is not rapid, and is accomplished with careful investigations as to the capabilities of the branches to bear his weight. The "Man of the Woods" has been stated to build a hut in trees. This is hardly true, but it does build a tree-nest.

One of these nests has lately been described by Dr. Moebius. It was found on the fork of a tree 11 meters above ground. Every night as it appears, or every second night, the animal constructs a new nest for himself, abandoning the old one. So numerous, therefore, are these nests in localities frequented by orangs, that a dozen can be readily found in a day. The particular nest which Dr. Moebius examined was 1.42 meters long, and at most .80 meters broad. It was built of about twenty-five branches, broken off and laid for the most part parallel to each other. Above the framework a number of loose leaves lay. There is no doubt, therefore, that these nests are not by any means elaborate and that they only serve as sleeping places and not as nurseries.

WHILE NOT A SKILLED TYPEIST "TILLIE" ENJOYS THE NOISE HER MACHINE MAKES

The orang seems to be usually of a fairly mild disposition; it will rarely attack a man unprovoked. But Dr. Wallace describes a female orang who "on a durian tree kept up for at least ten minutes a continuous shower of branches, and of the heavy-spined fruits as large as 32-pound shells, which most effectually kept us clear of the tree she was on. She could be seen breaking them off and throwing them down with every appearance of rage, uttering at intervals a loud pumping grunt, and evidently meaning mischief. The name given by the Fyaks to the orang is Miss Pappan."

This habit of occupying a nest for only a night or two appears to be general among the man-like apes. A German



AS THIS PICTURE INDICATES THE ORANG-UTAN IS AN ACCOMPLISHED ACROBAT BUT A POOR PEDESTRIAN OWING TO THE PECULIAR STRUCTURE OF THE HIP JOINTS

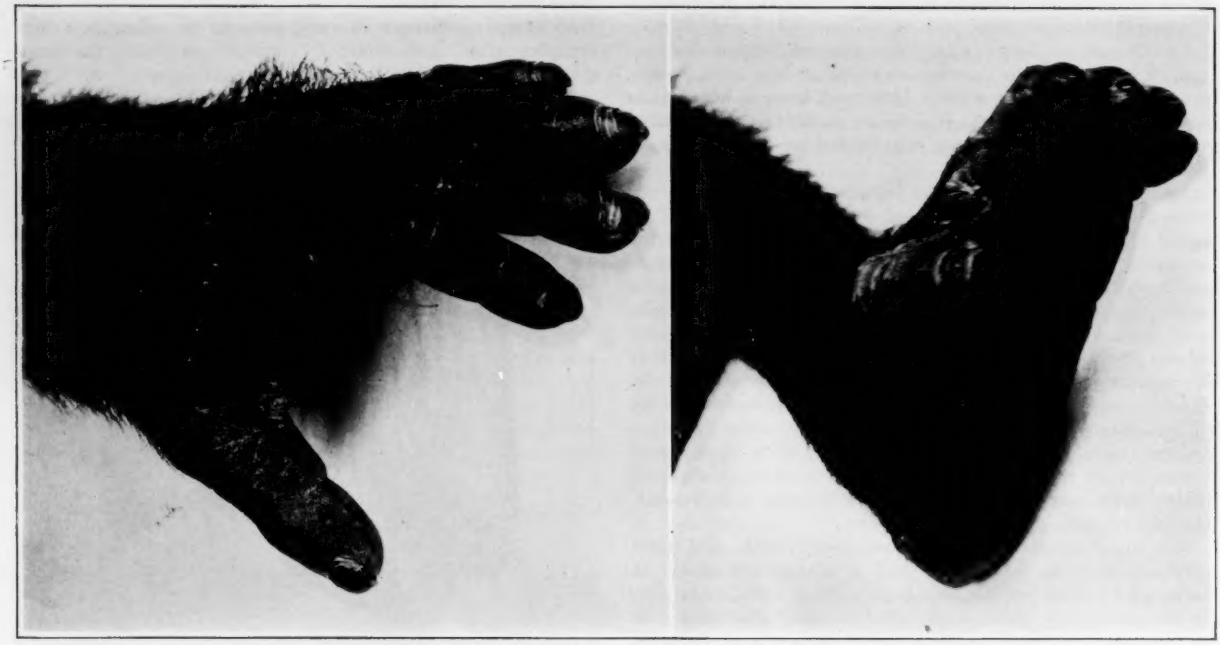
naturalist in Africa has recently published some unusually interesting observations made by him personally with regard to the nests of gorillas and chimpanzees. He remarks that the former may be regarded as the real inventor of the spring mattress by way of a bed!

THEIR FOOD

All of these apes live chiefly upon vegetable food. This is said to be diversified, however, by an occasional bird or small animal, while all monkeys are very fond of eggs, their arboreal habits making the robbing of birds' nests an easy matter for them. On a recent visit to the beautiful grounds and magnificent collection of animals of the New York Zoological Society in Bronx Park, near New York City, the writer questioned one of the keepers in the house of the primates concerning the food of these animals in captivity. He replied that they were practically as omniverous as man himself. The bulk of their food consists, of course, of fruit and cereals, particularly of the tropical fruit such as bananas, oranges and cocoanuts, to which they are accustomed in their native haunts. But they also eat bread and milk with relish and are occasionally given boiled beef or chicken by way of a special treat and for the sake of variety in the diet.

A lady of the writer's acquaintance once had rueful cause to remember that monkeys are fond of birds! While wearing a new bonnet adorned with a bird she approached a cage of monkeys to watch their gambols, when one of them suddenly thrust his hand through the bars, snatched the bird from her bonnet and instantly began to pluck it with great zest.

The monkeys in the New York Zoological Gardens are fed twice a day, at 2:30 and in the evening shortly before they retire, the latter meal consisting only of milk or bread and milk. It is amusing to watch them when the keeper opens the



THE HAND AND THE FOOT OF A CHIMPANZEE

Note the length of thumb and shortness of fingers of the hand, also the thumb-like character of the big toe and the naked sole of the foot

rear door of the cage and sets in the dish of supper. Sometimes they drink their milk from the bowl standing on all fours with the dish resting on the floor of the cage, but more commonly when the keeper remarks "supper is served" or words to that effect, they climb down from their lofty perch, grasp the dish in one hand, holding it level so as not to spill the precious fluid, and climb with the other three limbs back to their aerial station and seat themselves comfortably so that they can hold the bowl in both hands while drinking its contents. One of the big chimpanzees at the Zoo seems to enjoy dipping his bread in the bowl of milk and then sucking it luxuriously until the liquid has disappeared, and an amusing story is told of some monkeys in a collection of animals kept, we believe, at the Soldiers' Home in Dayton, Ohio, which when given slices of bread and butter, would calmly lick off the butter and hand back the bread for more.

THE ART OF MIMESIS

Next to the faculty of curiosity that of imitation is perhaps the most marked characteristic in the intelligence of simians. It is this quality, as we have said, which is most often held up to scorn in apes and monkeys, as is evidenced by such popular expressions of derogation as "aping one's betters," "playing monkey-tricks," "playing the sedulous ape," etc. But rightly considered this faculty, too, holds within its compass the seeds of progress toward better things. It was by "playing the sedulous ape" to his betters that Stevenson acquired his delightful style. Aristotle declared that the very essence of "Epos making and the making of tragedy, also comedy and dithyramb making, and most fluting and harping are . . . but imitations," and in commenting upon this Professor Gilbert Murray declares that man's ancestors from their tree-dwelling days onward stood out from all other animals by their marvelous powers of mimesis, and it was in this power coupled with the capacity for choice that he finds the real secret of their advance in knowledge and skill above the other beasts of the field.

Writing in a recent number of the *Yale Review*, he utters the following remarkable words concerning these primordial forebears of ours:

"When they met with a sort of conduct which they liked they had the power of imitating it, and, of course, the power of selecting for imitation the particular element in it that happened to appeal to them most. Sometimes they imitated badly and chose the wrong things; sometimes they seem like our poor relations in the Zoological Gardens today, to have imitated without any coherent plan or choice at all. But on the whole there has been a coherence in the main stream of human mimesis; we have imitated the things which we admired. . . . We have formed ideals, and our ideals have guided us. It is this power of idealism, this curious power of seeing what we like and admire and then trying to imitate it; of seeing things that were beautiful and trying to make others like them; of seeing things that roused interest or curiosity and trying by mimetic imagination to get inside them and understand them that has been the guiding force in the upward movement of humananity."

A PRIMARY CLASS FOR PRIMATES

The most intelligent of the man-like apes now in the New York Zoological Gardens is the large chimpanzee, Suzette, who is respectfully referred to by her keepers as a retired vaudeville actress, from her exploits upon the stage where only a few years ago she was a star performer upon the tight rope and bicycle. When the writer last saw Suzette she looked as sedate, however, as she does in the accompanying picture. It was about six o'clock by daylight saving time in the evening of a beautiful spring day, but in spite of the broad daylight which still prevailed Suzette, after finising her supper caught up an armful of straw in her left arm from the bottom of her cage, swung herself skilfully "upstairs" by her right hand, added the straw to the bedding already on her bunk and, drawing the drapery of her couch about her, lay down to pleasant dreams.

But the bright particular ornament of the primate house was the late-lamented Susie, the apt pupil, first of Professor Furness of Philadelphia, and then of the late Dr. Garner. Apropos of Susie's proficiency one of the keepers relates an amusing tale. After remarking that the great apes vary much like children, not only in intelligence but also in their proclivity for mischief making, he said that a few years ago the experiment was made of having Susie go through her

"stunts" before seven other chimpanzees, then owned by the Society. These seven little chimpanzees would be seated on chairs watching Susie, like good children "minding teacher," when suddenly little Dick, Susie's mate, and the most mischievous and least tractable of the lot, would jump from his seat, dart behind the row of attentive pupils, snatch the chair from beneath one of them and fly back to his place looking as solemn as an owl and as sober as a judge.

MAN AND THE MAN-LIKE APES DESCENDED FROM A COMMON ANCESTOR

Modern zoologists and anthropologists have come to the conclusion that man is not descended from any of the anthropoids but that *Homo* and his cousins, the great apes, have sprung from some common ancestor in the remote abyss of time. We cannot do better here than quote the conclusions stated by Gregory.

(1) Comparative anatomical (including embryological) evidence alone has shown that man and the anthropoids have been derived from a primitive anthropoid stock and that man's nearest existing relatives are the chimpanzee and gorilla.

(2) The chimpanzee and gorilla have retained with only minor changes, the ancestral habits and habitus in brain, dentition, skull and limbs, while the forerunners of the Hominidæ, through a profound change in function, lost the primitive anthropoidal habitus, gave up arboreal frugivorous adaptations and early became terrestrial, bipedal and predatory, using crude flints to cut up and smash the varied food.

(3) The ancestral chimpanzee-gorilla-man stock appears to be represented by the Upper Miocene genera *Sivapithecus* and *Dryopithecus*, the former more closely allied to, or directly ancestral to, the Hominidæ, the latter to the chimpanzee and gorilla.

(4) Many of the differences that separate man from the anthropoids of the *Sivapithecus* type are retrogressive changes, following the profound change in food habits above noted. Here belong the retraction of the face and dental arch, the reduction in size of the canines, the reduction of the jaw muscles, the loss of the prehensile character of the hallux. Many other differences are secondary adjustments in relative proportion, connected with the change from semi-arboreal semierect and semi-quadrupedal progression to fully terrestrial bipedal progression. The earliest anthropoids being of small size doubtless had slender limbs; later semi-terrestrial semierect forms were probably not unlike a very young gorilla, with fairly short legs and not excessively elongate arms. The long legs and short arms of man are due, I believe, to a secondary readjustment of proportions. The very short legs and very long arms of old male gorillas may well be a specialization.

(5) At present I have no good evidence for believing that the separation of the Hominidæ from the Simidæ took place any earlier than the Miocene and probably the Upper Miocene. The change in structure during this vast interval (two or more million years) is much greater in the Hominidæ than in the conservative anthropoids, but it is not unlikely that during a profound change of life habits evolution sometimes proceeds more rapidly than in the more familiar cases where uinterrupted progressive adaptation proceed in a single direction.

(6) *Homo heidelbergensis* appears to be directly ancestral to all the later Hominidæ.

PECULIARITIES IN THE SKIN OF NEGROES

THE skin of negroes varies from that of Europeans in certain important particulars and we are justified in concluding as a result of careful observation that its method of functioning is likewise different. Even when the temperature of the air is quite high the negro skin continues to feel cool; in spite of its dark color it suffers no injury from a solar irradiation sufficiently strong to raise blisters upon the white man's skin. Moreover, blacks appear to have an unusual sense of well being when in the sunshine. It is only exceptionally that one sees sweat collecting in drops upon their faces, but that there is an invisible perspiration present is made known by the peculiar and penetrating odor which proceeds from the skin. This appears to be due to a fatty acid allied to one of the butric acids and contrary to the general opinion it is entirely unconnected with personal uncleanliness; it is said, in fact, that not only do scrupulous ablutions fail to remove this odor but they even seem to make it all the stronger as soon as any violent muscular activity is performed.

This scent varies in strength in individuals. The skin of negroes seems to exercise the function of an excretory organ to a greater degree than does that of Europeans and the circulation of blood through it also appears to be more vigorous. A striking property of negro skin is its turgidity; it appears to be unusually thick and possesses a characteristic consistency which causes it to yield to pressure without feeling actually soft. The texture is coarser than that of the skin of Europeans and the ridges and grooves of the epidermis are more clearly defined, while even in the case of young people there are faint impressions like shallow furrows or cracks which change here and there into small wrinkles with advancing age. The surface of the skin often has an appearance of being slightly granulated, because of the prominence of the papillæ and the shallow dimple formed hollows between them. In contrast to the full, plump skin of the Bantu negro that of the Hottentot looks dry and withered. Even at a not very great age it tends to form wrinkles which causes persons still in middle life to seem quite aged. In really old persons this wrinkled aspect increases so much as to accentuate the ugliness of the face. At first very tiny wrinkles appear which can be plainly seen only on those parts of the body where the skin is very loose. Very soon, however, these small wrinkles begin to form groups and deep secondary wrinkles are formed which, finally, degenerate into actual furrows upon the skin and neck. These minute folds in the skin appear so early and in such abundance that they cannot be ascribed to declining age but must be regarded as a normal property of the skin of Hottentots. The Hottentots, however, are not afflicted with the peculiar penetrating odor which proceeds from the skin of African negroes.

The skin of the Bush folk is likewise remarkably dry from youth on and it has a peculiar texture which more than anything else resembles that of tanned morocco leather. Furthermore, just as the leather has lost a part of its elasticity from being tanned, so the skin upon the living body of the Bushman appears already to have become less elastic for on those parts of the body where it is subjected to a temporary stretching as in the neighborhood of the knee, the armpit, or the abdomen, it does not immediately spring back but falls into deep folds. While the formation of folds in the skin of the Hottentot represents a wrinkling which is less dependent upon the part of the body concerned and which is probably due chiefly to the early disappearance of the fatty tissue, in the Bushmen the elasticity of the skin itself is lost. Accordingly even the finest lines upon the surface of the skins of the two races differ from each other. While in the Hottentot the small folds run into the furrows of the skin, in the case of the Bushmen the skin has a much more irregular texture covered with broad cracks so that it resembles somewhat badly mishandled leather, whether the person is walking or standing. The main direction of these scarlike depressions by no means coincides with the longitudinal direction of the folds in the skin, but generally runs off from the latter at one or another obtuse angles.—This peculiarity may be seen even in the children of so-called domesticated Bushmen living upon farms. In fact this scarred and leathery aspect of the skin is seen even in boys about 13 years of age.—Translated for the *Scientific American Monthly* from the *Ntw. Umschau d. Chem.-Ztg.* (Berlin), for April, 1921.

Four Legged Birds That Climb Trees

The Hoatzin—A Missing Link Between Birds and Reptiles, Found in South America

By Donovan McClure

Photographs by Dr. C. William Beebe

ONE of the strangest birds in the world—a survival indeed from an earlier zoological age—is the graceful crested pheasant, found in British Guiana and known by various names, including the native term hoatzin derived from its harsh cry, not unlike the raucous scream of a guinea fowl; other names applied to this strange bird are "Anna,"

A YOUNG HOATZIN SCRAMBLING ALONG THE GROUND

"Hannah," "Canje," pheasants, Governor Battenberg's turkeys, the loco bird or "crazy" bird, the cigana or "gypsy" bird, and most unpleasant of all the "stinking" pheasant.

Distribution and Description.—This bird is widely found throughout South America, the countries where it has been observed including Colombia, Ecuador, Peru, Venezuela, Bolivia; Brazil, as well as British and Dutch Guiana. The bird was first described more than 250 years ago by Hernandez, in his Latin work "*Nova Plantarum, Animalium et Mineralium Mexicanorum Historia.* He is described in the following words:

"This is a bird of about the size of an Indian fowl; its beak is curved; its breast shades from white to buff; its wings and tail are spotted with white at intervals of a thumb's length; the back of the upper part of its neck is yellow, shading into blackish on both sides and sometimes extending as far as the beak and eyes; the claws are black and the legs blackish. The bird bears a sturdy crest of feathers, varying from white to yellowish, the back of each feather, however, being black. The bird subsists upon snakes. It has a powerful voice, which resembles a howling or wailing sound. It is heard in the autumn and is held inauspicious by the natives.

"The bones of this bird relieve the pain of wounds in any part of the human body; the odor of the plumage restores hope to those who, from disease, are steadily wasting away. The ashes of the feathers when devoured relieve the gallic sickness, acting in a wonderful manner.

"The bird lives in warm regions, such as Yauhtepeceusis, generally establishing itself in trees growing along the banks of the streams, where we, having observed it, captured it, and making a drawing of it, kept it alive."

This description is said by Mr. C. William Beebe, the greatest living authority upon the subject, to be fairly accurate, except, of course, as regards the medieval medical ideas and the statement that the bird's food consists of snakes.

Food.—As a matter of fact the bird is vegetarian in habit and its food consists almost entirely of two or three species of marsh plants; one of these is the mucka-mucka or arum (*Montrichardia ardorescens*) a tall plant with large heart-shaped leaves and a fruit resembling a pineapple. The bird feeds upon the leaves, flowers and fruit. The food also includes the tough leaves of the white mangrove and several varieties of wild fruit, including the sour guava.

GENERAL CHARACTERISTICS

While the hoatzin strongly resembles a pheasant in general appearance, it also reminds one of a peacock, especially as regards the bearing of the neck and head, as well as in the graceful crest. The bird has a short, strong beak of peculiar shape, well adapted to deal with the sturdy vegetation upon which it feeds. Its total length is about twenty-three inches, the wing 12½ inches long, the tail 12, the tarsus 2, and the middle toe and claw 3. The plumage of the body is very loose; the wings and tail are large as compared to the body and are furnished with strong well knit feathers, a rather surprising fact since the bird has a very weak flight. When sitting quietly, either perching or on its nest it is extremely hard to discern, because of its admirable protective color, but when it takes flight it at once becomes extremely conspicuous.

Peculiar Features.—The most strikingly peculiar features of the hoatzin, however, consist in its unique structure, a survival of a prehistoric age, in its singular crop, and in its offensive odor.

The scientific name of the bird is *Opisthocomus hoazin*, and it is such an extremely ancient and entirely isolated type, that it has been set aside in a separate order by itself—the order of *Opisthocomiformes.* It possesses a vestigial claw on the third digit which links it with the primitive *Archaeopteryx.*

YOUNG HOATZIN CLIMBING A TREE WITH THE AID OF CLAWS ON ITS WINGS

Another claim which it possesses to be regarded as a primitive form consists in the fact that the young birds behave like quadrupeds, whence our title of four-legged birds. They have unusually well-developed forelimbs and "fingers" and possess external claws on the first and second finger, which they make use of in climbing vigorously about the bushes which surround the nest. This habit is strikingly described by an American naturalist, Mr. Edward Brigham, who observed it

while making a collection of the embryos of vertebrates in the Island of Marajo at the mouth of the Amazon. He noticed that shortly before the egg was hatched two complete toes appeared at the ends of the forelimbs (wings) which suggested to him the probability that they were intended for some special service. Shortly afterward he had the pleasure of finding that his surmise was correct. He writes:

"One day in June while rowing upon the lower waters of the Rio Negro, the natives pushed our boat into the edge of an *igapo* or submerged forest. The water was visible between the tops of the trees. Evil-looking alligators snorted, barked, and roared as they glided among the half-submerged tree tops. Enormous iguanas sunning themselves upon the highest branches from three to six yards above our heads in unusual numbers, dived suddenly head first in the igapo. Never before had I been witness to so interesting a scene of reptile life. My curiosity was increased by the presence of the hoatzins, who were screeching and quarreling around me. I was particularly interested in the demonstration before me since I had been engaged in studying the vestiges of a reptile origin found in the anatomy of these birds. I had a distinct impression, in fact, that I was somehow engaged in watching a scene in the Mesozoan age. Buried in these thoughts my attention was suddenly attracted toward the lowest branches of the trees by a plunge which appeared to be different from that of the iguanas, as if some other kind of animal had slid into the water. Very close to this point I then caught sight of a young hoatzin sitting upon a low branch. The Indians told me that the noise I had heard had been made by a young cigana diving into the water. I ordered them to catch the other one which we saw, but it likewise dived and disappeared. Shortly afterward, however, we saw the first bird emerge from the water and climb up a submerged branch on *all fours*. An Indian killed the bird and I prepared its skin, at the same time pointing out to my men the *anterior claws*. They seemed astonished by the sight but after some reflection an old man said: 'The young siganos climb out of the water with those feet there.' The presence of the toes upon the wings made clear to him the explanation of the phenomenon with which he was familiar but which had always remaind a mystery to him."

Mr. Brigham ascribed the feeble powers of flight of the bird noted above to this habit of climbing like a quadruped during a long period of development. It should be noted, further, that the sternum or the breast bone has no "keel" and, consequently, it appears to be impossible for the young bird to get out of the water except by means of climbing, but since they do not possess webbed feet their wings are more useful in escaping enemies than is their ability to dive.

The Crop.—This reduction of the front part of the keel of the sternum is a condition which is absolutely unique among birds, and it is a direct result of the peculiar character of the crop. This organ has, in fact, assumed the structure and importance belonging to the gizzard in other birds. Its walls are thick and muscular instead of being flabby and glandular, and it has increased in size very greatly, measuring about 2½ inches in diameter when extended with food.

The Foetid Odor.—Various conflicting statements are made as to the nature of the unpleasant odor emanating from the flesh of the hoatzin and its cause. It is sometimes said to be so frightful that it is only possible to skin the birds under water. Some authorities ascribe it to the aroid shrub upon which it feeds. It is variously described as reminding one of a strong cow shed and as resembling a mingling of musk with wet cattle hides, but Dr. Beebe has the following to say, regarding this point, in a report made to New York Zoological Society.

"On our Venezuelan trip we were warned again and again concerning the frightful odor supposed to characterize these birds. Some said they would have to be skinned under water! We found this wholly false. When skinning or dissecting one of these hoatzins one notices the faintest of musky odors, not at all unpleasant, and indeed perceptible only when the attention is directed to it. Our specimens were certainly most inoffensive in this respect, and the flesh of one which we cooked and ate, while it was tough, was as clean and appetizing as that of a curassow.

"In British Guiana the above experience was repeated, although the 'stinking pheasant' was held in horror by the blacks. But as before, we could detect nothing but a slightly musky odor. The odor is exceedingly persistent and is given off by skins which are several years old. Its cause is problematical and the direct connection with the crop is very doubtful. There is little doubt but that hoatzins differ greatly, either seasonably or individually, in regard to the intensity of this odor. Far be it from me, however, to emphasize any lack of it, for the very thread of existence of this most interesting bird hangs upon belief in this inedibility."

MATING HABITS

The hoatzin is monogamous and both sexes assist in building the nests which are woven of twigs and sometimes placed in a crotch of a tree or more rarely supported by several branched mucka-mucka stems. There are usually two eggs in the nest though sometimes three or four are found. They are variable in shape, being sometimes elliptical and sometimes oval. The size averages 1.8 by 1.3 inches. The ground color is creamy white. The entire surface is marked with small, irregularly shaped dots and spots of reddish brown, inclining to be more abundant at the large end. The brown pigment deposited early in the oviduct is covered by a thin layer of lime and thereby given a lavender hue.

NEW STUDIES AT THE TROPICAL RESEARCH STATION

In 1916 Dr. Beebe took charge of the Tropical Research Station established in British Guiana, under the auspices of the New York Zoological Society, together with two assistants and two artists, the enterprise being made possible by the generosity of a group of well-known New Yorkers. During the period of residence from March to August, Dr. Beebe was able to extend his observations concerning this strange and interesting bird which he terms "a reptile-like living fossil." In his report of the trip published is 1917, he gives the following entertaining account of the quaint nestlings and their solicitous parents:

"The nestlings in seven occupied nests observed as we drifted along shore or landed and climbed among the thorns, were in an almost identical stage of development . . . their down was a thin, scanty, fuzzy covering, and the flight feathers were less than a half inch in length. No age would have showed to better advantage every movement of wings or head.

"When a mother hoatzin took reluctant flight from her nest, the young bird at once stood upright and looked curiously in every direction. No slacker he, crouching flat or waiting his mother's directing cry. From the moment he was left alone he began to depend upon the warnings and signs which his great beady eyes and skinny ears conveyed to him . . . but one little hoatzin failed to count on the invariable exception to every rule, for this day the total unexpected happened, and fate, in the shape of enthusiastic scientists, descended upon him. He was not for a second disconcerted . . . and we found him no mean antagonist and far from reptilian in his ability to meet new and unforeseen conditions.

"His mother, who a moment before, had been packing his capacious little crop with predigested pimpler leaves, had now flown off to an adjoining group of mangroves, where she and his father croaked hoarse encouragement. His flight feathers hardly reached beyond his finger tips and his body was covered with a sparse coating of sooty black down. So there could be no resort to flight. He must defend himself, bound to earth like his assailants.

"Hardly had his mother left when his comical head, with thick, blunt beak and large intelligent eyes, appeared over the rim of the nest. His alert expression was increased by the suspicion of a crest on his crown, where the down was slightly longer. Higher and higher rose his head, supported on a neck of extraordinary length and thinness. No more than

this was needed to mark his absurd resemblance to some strange, extinct reptile. A young dinosaur must have looked much like this, while all that my glance revealed, I might have been looking at a diminutive Galapagos tortoise. Indeed this simile came to mind often when I became more intimate with nestling hoatzins. Sam, my black tree climber, kicked off his shoes and began creeping along the horizontal limbs of the pimplers. At each step he felt carefully with each calloused sole in order to avoid the longer of the cruel thorns, and punctuated every yard with some gasp of pain or muttered personal prayer, 'please, don' stick me, thorns!' At last his hand touched the branch, and it shook slightly. The young bird stretched his mittened hands high above his head and waved them a moment. With similar intent a boxer or wrestler flexes his muscles and bends his body. One or two uncertain forward steps brought the bird to the edge of the nest and at the base of a small branch. There he stood and raising one wing leaned heavily against the stem, bracing himself. My man climbed higher and the nest swayed violently. Now the brave little hoatzin reached up to some tiny side twigs and aided by the projecting ends of dead sticks from the nest, he climbed with facility, his thumbs and forefingers apparently being of more aid than his feet. It was fascinating to see him ascend, stopping now and then to crane his head and neck far out, turtle-wise. He met every difficulty with some new contortion of body or limbs, often with so quick or so subtle a shifting as to escape my scrutiny. Once he even chinned himself. The branch ended in a tiny crotch and here, perforce, ended his attempt at escape by climbing. He stood on the swaying twig, one wing clutched tight and braced with both feet. Nearer and nearer crept Sam. Not a quiver on the part of the little hoatzin. We did not know it, but inside that ridiculous head there was definite decision as to a deadline. He watched the approach of this great strange creature, this danger, this thing so wholly new and foreign to his experience and doubtless to all the generations of his forebears. A black hand grasped the thorny branch six feet from his perch, and like a flash he played his next trick—the only remaining one he knew, one that set him as apart from all modern land birds as is the frog from the swallow.

"The young hoatzin stood erect for an instant, and then both wings of the little bird were stretched straight back, not folded, bird-wise, but dangling loosely and reaching well beyond the body. For a considerable fraction of time he leaned forward. Then without effort, without apparent leap or jump he dived straight downward, as beautiful as a seal, direct as a plummet and very swiftly. There was a scarcely noticeable splash and as I gazed with real awe, I watched the widening ripples which undulated over the muddy water, the only trace of the whereabouts of the young bird.

"It seemed as if no one, whether ornithologist, evolutionist, poet, or philosopher could have failed to be profoundly impressed at the sight we had seen. Here I was in a very real, a very modern boat, with the honk of motor horns sounding from the river road a few yards away through the bushes, in the shade of this tropical vegetation in the year nineteen hundred and sixteen, and yet the curtain of the past had been lifted, and I had been permitted a glimpse of what must have been common in the millions of years ago. It was a tremendous thing, a wonderful thing to have seen and it seemed to dwarf all the strange sights I had seen in all other parts of the earth's wilderness. I had read of these habits and had expected them, but like one's first sight of a volcano in eruption, no reading or description prepares one for the actual phenomenon.

"I sat silently watching for the reappearance of the young bird. We tallied five pairs of eyes and yet many minutes passed before I saw the same little head and emaciated neck sticking out of the water alongside a bit of drift rubbish. The only other visible thing was the protruding spikes of the bedraggled tail feathers. I worked the boat in toward the bird, half-heartedly, for I had made up my mind that this brave little bit of atavism deserved his freedom, so splendidly had he fought for it among the pimplers. Soon he ducked forward, dived out of sight and came up twenty feet away among an inextricable tangle of vines. I sent a little cheer of well wishing after him and we salvaged Sam.

"Then we shoved out the boat and watched from a distance. Five or six minutes passed and a skinny, crooked two-fingered mitten of an arm reared upward out of the muddy flood and the nestling, black and glistening hauled itself out of the water. Thus must the first amphibian have climbed out, shaken the water from its eyes and gasped in the thin air. But the young hoatzin neither gasped nor shivered, and seemed as self-possessed as if this were a common occurrence in its life. There was not the slightest doubt, however, that this was its first introduction to water. Yet it had dived from a height of fifteen feet, about fifty times its own length, as cleanly as a seal leaps from a berg. It was as if a child should dive two hundred feet!

"In fifteen minutes more it had climbed high above the water and with unerring accuracy directly toward its natal bundle of sticks overhead. The mother now came close and with hoarse, rasping notes and frantic heaves of tail and wings lent encouragement. Just before we paddled from sight, when the little fellow had reached his last rung, he partly opened his beak and gave a little falsetto cry—a clear, high tone, tailing off to a guttural rasp. His splendid courage had broken at last; he had nearly reached the nest and he was aching to put aside all this terrible responsibility, this pitting of his tiny might against such fearful odds. He wanted to be a helpless nestling again, to crouch on the springy bed of twigs with a feather coverlet over him and be stuffed at will with delectable pimpler pap. Such is the normal destiny of a hoatzin chick and the wheee-og! wrung from him by the reaction of safety, seemed to voice all this."

A curious circumstance is that the wing claws molt; in the nestling of a fortnight they are sharp and curved like those of a cat. But the claws on both thumb and forefinger are shed at least twice in the first four months.

In feeding, the nestling cranes its neck upward and thrusts its head well down the mother's throat for from 10 to 20 seconds.

They swim well, using the feet alone, but are extremely clumsy on the ground—"as helpless as seals"—pulling themselves clumsily along by the wing claws while the feet kick out behind in a futile manner.

CURIOUS FACTS ABOUT THE CUCKOO'S EGG

JUST as the cuckoo is one of the most baffling of birds to the ornithologist, so its egg presents suprising peculiarities. While birds' eggs possess a uniform and distinctive character as to their color and markings, that of the cuckoo commonly exhibits a likeness to those of the involuntary foster parents. Thus we find white, green and blue cuckoos' eggs; some with only a few speckles, while others are elaborately variegated.

This mimicry was the subject of an address by Lieut. von Lucanus before the German Ornithological Society in Berlin. He stated that of 765 cuckoo eggs in the Berlin Natural History Museum 575 strikingly resembled the eggs of the foster parent in color and marking; 169 were entirely unlike those of the deceived bird, and 120 of those had been laid in the wren's nest. Of the first lot 502 were in the nest of the warbler or hedge sparrow. The eggs of the garden warbler vary considerably in color and marking, which favors the deception by the cuckoo.

Other instances in which the hostess' egg closely resembles the invader's include the gray fly catcher, the white wagtail, and the Asiatic yellow hammer. In the latter case the resemblance is really remarkable, since the egg of this bird is peculiarly characteristic, being of a white ground with dark brown twisted scrawls and vermiform lines forming a wreath about the big end of the egg! Who will solve this riddle? asks the *Naturwissenschaftliche Umschau* (Berlin), for April, 1920.

Flower-Like Fauna of the Sea

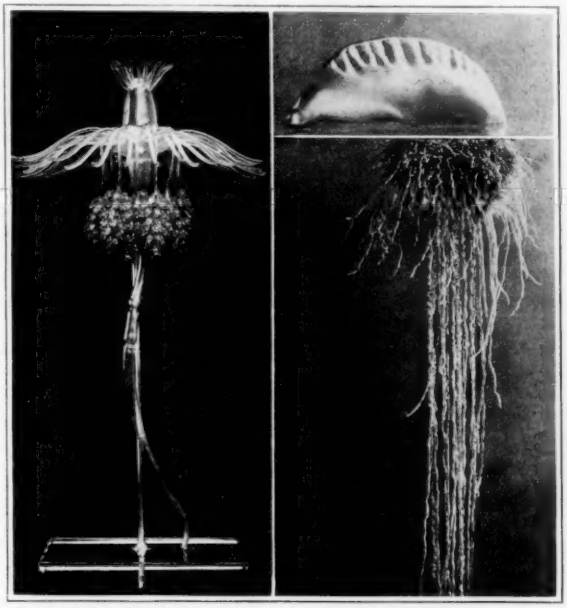
Sea Anemones, Jelly Fish and Other Members of the Coelenterata

By T. A. Marchmay

Illustrated with photographs of models in the American Museum of Natural History

THE creed of the systematic is to have a place for everything and everything in its place, a slogan which some ingenious not to say disorderly person has neatly twisted into "have a place for everything and put everything in that place." This suggests the difference between the structure of the vertebrates and that of the large family or *phylum* known as the *Coelenterata*. In the former the various functions involved in the process of life, nutrition, elimination, circulation, respiration, and reproduction are assigned to separate organs of definite location and highly complex nature as well as greatly differentiated in character. In the *Coelenterata*, on the other hand, all these functions are carried on in a single organ, the bag-like body or *Coelenteron* of the animal.

This coelenteron is from one point of view as simple in structure as a lady's reticule, since it consists mainly of two layers of cells like the material and the lining of the reticule. These inner and outer layers are divided, however, by a stratum of a jelly-like substance, which is sometimes quite thick and sometimes very thin.



AN UMBRELLA-LIKE HYDROZOAN

THE PORTUGUESE MAN-OF-WAR

The external shape of these creatures is extremely various and curious in spite of the simplicity of the main portion of the body. This variety of form is due to the fact that the appendages of the body are radiating in character. While they are quite symmetrical it is not a bilateral symmetry such as vertebrates possess, but a *radial* symmetry.

This radial symmetry has been acquired and has no further significance than the adaptation of different animals to somewhat similar conditions of life. It is not only in the animals formerly classed by Cuvier as Radiata, but in sedentary worms, Polyzoa, Brachiopoda, and even Cephalopoda among the mollusca, that we find a radial arrangement of some of the organs. It is interesting in this connection to note that the word "polyp" so frequently applied to the individual coelenterate animal or zooid, was orignally introduced because of a fancied resemblance of a *Hydra* to a small cuttlefish (*Fr.* Poulpe, *Lat.* Polypus).

The body of the coelenterate, then, consists of a body-wall enclosing a single cavity ("coelenteron"). The body-wall consists of an inner and an outer layer of cells, originally called by Allman the "endoderm" and "ectoderm" respectively. Between the two layers there is a substance chemically allied to mucin and usually of a jelly-like consistency, for which the convenient term "mesogloea," introduced by G. C. Bourne, is used.

The mesogloea may be very thin and inconspicuous, as it is in *Hydra* and many other sedentary forms, or it may become very thick, as in the jelly fishes and some of the sedentary *Alcyonaria*. When it is very thick it is penetrated by wandering isolated cells from the ectoderm or endoderm, by strings of cells or by cell-lined canals; but even when it is cellular it must not be confounded with the third germinal layer or mesoblast which characterizes the higher groups of animals, from which it differs essentially in origin and other characters. The Coelenterata are two-layered animals (*Diploblastica*), in contrast to the Metazoa with their three layers of cells (*Triploblastica*). The growth of the mesogloea in many Coelenterata leads to modifications of the shape of the coelenteric cavity in various directions. In the Anthozoa, for example, the growth of vertical bands of mesogloea covered by endoderm divides the peripheral parts of the cavity into a series of intermesenterial compartments in open communication with the axial part of the cavity; and in the jelly fishes the growth of the mesogloea reduces the cavity of the outer regions of the disk to a series of vessel-like canals.

Another character of great importance possessed by all Coelenterata is the "nematocyst" or "thread-cell." This is an organ produced within the body of a cell called the "cnidoblast," and it consists of a vesicular wall or capsule, surrounding a cavity filled with fluid containing a long and usually spirally coiled thread continuous with the wall of the vesicle. When the nematocyst is fully developed and receives a stimulus of a certain character, the thread is shot out with great velocity and causes a sting on any part of an animal that is sufficiently delicate to be wounded by it. It resembles, in short, a minute harpoon.

The morphology and physiology of the nematocysts are very complex. By some authorities it is supposed that the cnidoblast is a highly modified form of mucous or gland cell, and that the discharge of the nematocyst is subject to the control of a primitive nervous system that is continuous through the body of the zooid.

The Coelenterata are divided into four classes:

1. *Hydrozoa.*—Without stomedacum (*i.e.*, the anterior part of alimentary canal) and mesenteries. Sexual cells discharged directly to the exterior.

2. *Scyphozoa.*—Without stomedacum and mesenteries. Sexual cells discharged into the coelenteric cavity.

3. *Anthozoa-Actinozoa.*—With stomedacum and mesenteries. Sexual cells discharged into the coelenteric cavity.

4. *Ctenophora*, including comb-jellies.

The full meaning of the brief statements concerning the structure of the classes given above cannot be explained until the general anatomy of the classes has been described. It may be stated, however, in this place that many authors believe that structures corresponding with the stomedacum and mesenteries of Anthozoa do occur in the Scyphozoa, which they therefore include in the class Anthozoa.

Among the more familiar animals included in the class

of Hydrozoa may be mentioned the fresh-water polyp *Hydra*, the *Hydroid* zoophytes, many of the smaller Medusae or jelly-fish, the Portuguese Man-of-War (Physalia), and a few of the corals.

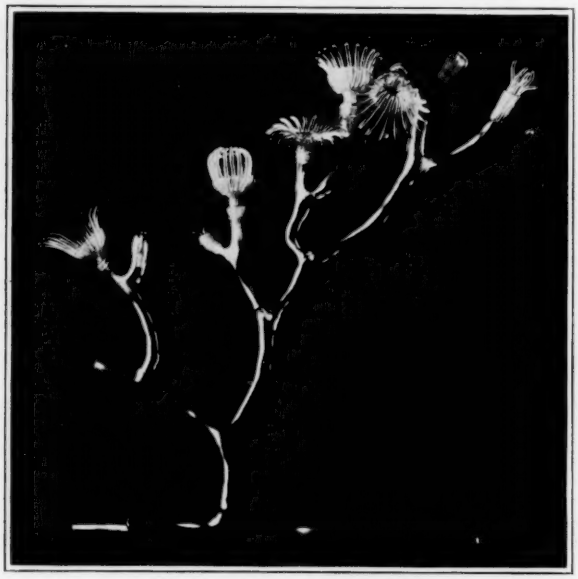
Included in the Scyphozoa are the large jelly-fish found floating on the sea or cast up on the beach on shores.

The Anthozoa include the sea-anemones, nearly all the stony corals, the sea-fans, the black corals, the dead-men's fingers (Alcyonium), the sea-fans, and the precious coral of commerce.

These classes are based upon the arrangement of the eggs.

The number of divisions formed by the radiating partitions mentioned above vary with the different species and also according to age. Other partitions start from the outer sac and extend toward the central axis but do not unite with it. These partitions, which are known as *mesenteries* are always in definite multiples; they vary in different species, new divisions growing between the first partitions in regular order.

The Eggs.—The eggs of the animal are formed on the inner edge of the partitions and when they are ripe they drop into



BRYZOA OR MOSS ANIMALS
They are of compound structure with sheath-like envelope and circle of tentacles

the divisions or "chambers" mentioned above, and pass through openings in these into the central cavity or "stomach," whence they pass through the mouth into the water. These creatures are classified according to whether the eggs are formed on all or on special partitions; those in which there is a limitation and constancy of function are regarded as being of the highest order.

In all the coelenterates or polyps, as many of them are called, the mouth serves not only for the taking in of food and the expulsion of the eggs, but also for the elimination of the waste matter which results from the digestion and assimilation of the food and the replacing of worn tissues.

HYDROZOA

Among the hydrozoa there are two types in the form of the body. In some genera, such as the *Obelia*, there is a fixed branching colony of the animals, each of which is known as a zooid; these consist of a simple tubelike body composed of the two layers of cells referred to above, the ectoderm and the endoderm. This tube ends in a conical mound in the middle of which is the mouth which is surrounded by a ring of tentacles. This fixed colony increases in size much like a yeast plant does by the putting forth of buds, a process known as gemmation, since it produces no sex cell. But at a certain season of the year a number of the buds on the parent colony develop into small bell-shaped jelly fish, each of which is called a Medusa; these medusae swim away from the parent colony and enjoy a separate existence. Moreover, they proceed, when sufficiently mature, to develop sex cells. Thus we have an extremely interesting example of the always fascinating phenomenon known as the alteration of generations—a phenomenon generally supposed to be found in a somewhat limited number of plants and animals, but which certain recent investigators declare to be found in all forms of life from the highest to the lowest. (See SCIENTIFIC AMERICAN MONTHLY for May, 1921). The medusae are very graceful and pretty. The little creature is like a delicate fairy bell in shape and its mouth is fringed with tentacles; there is even a sort of clapper to this dome-shaped and contractile bell, consisting of a tube extending from the center and having the mouth at its lower end. Sometimes these tentacles are solid and sometimes they are hollow, containing a cavity connected with the main cavity in the body.

In the Medusa stage the hydra is naturally more complicated in structure so as to adapt it to the more varied conditions of life found by a free-swimming creature. The bell of the Medusa or the "umbrella" as it is sometimes called, is perforated by small radiating tubes or canals. Along the margin of the umbrella or at the base of the tentacles are found certain opaque red or blue spots, called ocelli and supposed to be sense organs. Other spots similarly located are known as statocysts.

A specially interesting genus is the *hydra* which is one of the few examples among the coelenterates which is found exclusively in fresh water; it is very widely distributed, being found not only in Europe and North America, but in New Zealand, Australia and the tropical portions of Central Africa and Central America. In temperate zones it is commonly found in clear, still, fresh water, attached to the stems or leaves of water plants. When fully extended its tubular body may be as much as 25 mm. in length, but in a completely retracted state the same individual will be only about ⅛ as long. During most of the summer the colony increases by gemmation. The young hydra so produced themselves produce buds, but usually not until after they have left the parent.

The reproductive process of this animal is peculiar in that the individuals may be either male, female, or double-sexed, and the condition appears to depend upon the relative abundance of the food supply. According to a well-known German naturalist when hydras have been well fed most of them become females; when the food supply has been greatly restricted the majority become males, and when the food supply is moderate in amount the majority become double-sexed. The gonads are simply clusters of sex cells situated in the ectoderm. There is no evidence either in their structure or their development to show that they represent reduced medusi form gonophones. The testis produces a number of minute spermatozoa. In the ovary, however, only one large yolk-laden egg-cell reaches maturity by the absorption of the other eggs. The ovum is fertilized while still within the gonad, and undergoes the early stages of its development in that position. With the differentiation of an outer layer of cells a chitinous protecting membrane is formed, and the escape from the parent takes place. It seems probable that at this stage, namely, that of a protected embryo there is often a prolonged period of rest, during which it may be carried by wind and other agencies for long distances without injury. (Vide Cambridge Royal Nat. History).

The remarkable power that the hydra possesses of recovery from injury and of regenerating lost parts was first pointed out by Trembley in his classical memoir.

A *Hydra* can be cut into a considerable number of pieces, and each piece, provided both ectoderm and endoderm are represented in it, will give rise by growth and regeneration to a complete zooid. There is, however, a limit of size below which

fragments of *Hydra* will not regenerate, even if they contain cells of both layers. The statement made by Trembley, that when a *Hydra* is turned inside out it will continue to live in the introverted condition has not been confirmed, and it seems probable that after the experiment has been made the polyp

SEA ANEMONES—A NEW ENGLAND ACTINIA
The stomach at the center is surrounded by tentacles which capture its food

remains in a paralyzed condition for some time, and later reverts, somewhat suddenly, to the normal condition by a reversal of the process. There is certainly no substantial reason to believe that under any circumstances the ectoderm can undertake the function of the endoderm, or the endoderm the functions of the ectoderm so far as has been observed.

One of the characteristic features of *Hydra* is the slightly expanded disk-shaped extremity opposite the mouth usually called the "foot," though "sucker" would be a better term. There are no root-like tendrils or processes for attachment to the support such as are found in most of the solitary Gymnoblastea. The attachment of the body to the stem or weed or surface-film or other point of support by this sucker enables the animal to change its position at will. It may either travel slowly by sliding along its support without using the tentacles as do many sea-anemones, or more rapidly by a series of somersaults, as originally described by Trembley. The latter mode of locomotion has been recently described as follows: "The body, expanded and with expanded tentacles, bends over to one side. As soon as the tentacles touch the bottom they attach themselves and contract. Now one of two things happens: the foot may loosen its hold on the bottom and the body may contract. In this manner the animal comes to stand on its tentacles with the foot pointing upward. The body now bends over again until the foot attaches itself close to the attached tentacles. These loosen in their turn, and so the *Hydra* is again in its normal position. In the other case the foot is not detached, but glides along the support until it stands close to the tentacles which now loosen their hold."

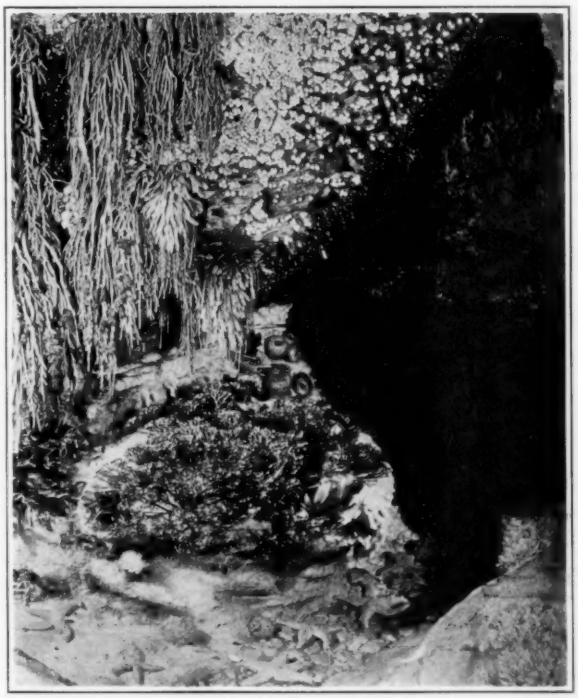
The *Hydra* appears to be purely carnivorous. It will seize and swallow *Entomostraca* of relatively great size so that the body-wall bulges to more than twice its normal diameter. But smaller crustacea, anolid worms and pieces of flesh are readily seized and swallowed by a hungry hydra.

While, as we have said, it is a characteristic feature of all the coelenterates to possess stinging organs, that of the hydra is especially worth describing because of the availability of this wide-spread little animal for study, even by amateurs. In a delightful book, recently published, *Aquatic Microscopy for Beginners*, by Alfred C. Stokes, this sting and the hydra's manner of using are thus entertainingly described:

"The food consists of small worms, water fleas, etc., or even of little pieces of raw beef if the observer chooses to feed them to the hydra. They seize the living victim as it is swimming by and twining a tentacle around it, draw the struggling creature to the mouth through which it is thrust into the stomach. The act of seizure takes place so rapidly that the eye can seldom follow it. The observer can usually know that the prey is caught only by seeing it slowly approaching the oral aperture. Often, when the captured object is too large or strong for one arm to hold several tentacles bend over and twine around it. A creature once caught rarely escapes.

"The writer has amused himself, and doubtless pleased the hydra, by feeding them with small larvæ or with aquatic worms. Take in the forceps a small aquatic worm by one end, and present the wriggling thing to a hydra's arm. No second invitation is needed. The worm is quickly embraced. If too long to be swallowed all at once part of it will hang out of the mouth until the other end is digested; the tentacles in the meanwhile will not cease to fish for more.

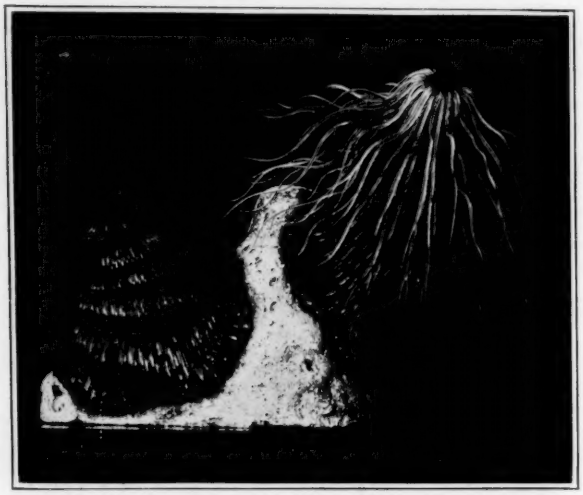
"The body and tentacles of the *Hydra vividis* are roughened by little elevations or warty prominences. The brown species is not so much roughened. These protuberances contain what are called the stings, small, oval, or vase-shaped hollow bodies, with a fine thread coiled in the interior, and four minute spines near the summit. When the hydra is irritated by the pressure of the cover-glass these stings are thrown out violently, and the long stiff thread can be well seen; when in the animal's body they cannot be so easily examined. They are often found on the side when no hydra is to be seen. They are sometimes noticeable sticking in the body of some worm or larva that has escaped a fatal embrace. The writer has more than once found a *Chironomus* larva in a dying condition and ornamented by a spiral band of these stings in its skin. It had evidently had a tussle with a hydra and escaped."



TIDAL POOL AT NAHANT, MASS., UNUSUALLY RICH IN SEA ANEMONES AND OTHER PICTURESQUE GROWTHS

The Millepores.—The Hydrozoa also include the millepores, which are colonies of zooids or zoophytes (*i.e.*, animal plants),

to use the older term, which secrete a stony skeleton instead of a horny one; they resemble in this respect the true corals but differ from them in other ways so as to come under a different class. The essential difference between the genus *Millepora* (literally a thousand pores) and the true corals is that in the former the different members of the colony have different functions to perform for the common welfare of the community, while in the true corals, which are likewise



CLADACTUS COSTA—A SEA ANEMONE WITH GRACEFUL THREAD-LIKE TENTACLES

grouped in communities, each member is a complete individual. Another marked difference is in the arrangement of the stony partitions, which in the millepores are the outside covering and connecting canals, while in true corals they are vertical partitions inside the animal between the inner and outer sacs. One of the most beautiful of these millepores is *M. alcicornis* or elk-horn coral which is found abundantly in Florida, and has helped to build the reefs off the coast of that state.

We must not leave the subject of the Hydrozoa without mentioning that many of their colonies resemble seaweed while others are like tufts of moss, fronded leaves or even feathers. Common along the coast of New Jersey and northward are the *Sertularia argentia* whose colonies are often more than a foot long with thickly growing silvery branches on a darker stem, and the *S. cupressina* or sea cypress. One of the most beautiful of all hydroids resembles an ostrich plume. Its scientific name is *Aglaophemia struthioides*.

Another hydroid famous for its ethereal delicacy and beauty is the Portuguese Man-of-War, which is one of the most remarkable examples of an animal community in all nature. This member of the hydrozoa belongs to the order Siphonophora and the genus Physalia, while its proper name is *P. arethusa*. As our illustration shows the most prominent part of the compound body is the pear-shaped bag called the float; this rests upon the surface of the water and is filled with air. This delicate structure presents exquisite changing tints of rose and azure, so that it is like a huge sweet pea blossom drifting upon the water. It is, however, about the size of a large pear. Along its top is a crest which takes the wind like a sail, while long tentacles or streamers hang down into the water, being massed near the broader end of the float. The longest of these tentacles are on the outside and serve to keep the crest or sail spread before the wind; when the latter is very strong they extend themselves to a really remarkable length—from 40 to 50 feet; they thus act as anchors to keep the colony from being driven toward the shore. Furthermore, they act as steering apparatus changing the course of the colony by raising the pointed end of the float and thus forcing it to come about.

Some of these tentacles are covered with stinging cells or cells as they are picturesquely called; these obviously represent the military class of the community; some are the feeding zooids who have charge of the commissary department, as we may say. These zooids whose function it is to absorb nutriment for the community have flask-shaped bodies, others look like clusters of grapes and it is the function of these to perpetuate the species.

The second division of Coelenterates, the *Scyphozoa*, are almost all when full grown, of Medusa type, and for this reason they are sometimes known as scyphomedusæ; they are jelly fishes and are usually found floating on or near the surface of the sea. While some species are only an inch or two in diameter, others are very large, including, indeed, the largest individual zooids found among the coelenterates. Some of these have a disk or umbrella 3 or 4 feet or even 7 feet or more in diameter and a specimen obtained in the Antarctic Expedition of 1898-1900 weighed no less than 90 pounds. The color is very variable and beautiful and it is this together with the graceful form and the floating fringe of tentacles which makes one instinctively compare them with flowers. A soft milky blue or opalescent tint is the most general, but many species show shades of green, blue, brown and purple. The tissues of these medusæ are, in general, less transparent than in the medusa form of the hydrozoa described above. The deep sea species are, generally, dark red or opaque brown in color. While the color is generally uniformly distributed, sometimes it occurs in irregular brown or yellow patches like freckles. Sometimes brighter spots of color appear on the tips of the tentacles and the lips of the mouth, and it is thought by some naturalists that these brighter tints may act as a bait in attracting small fish and crustaceans.

Some of the Scyphozoa are phosphorescent and it is these which form the lines of white fire seen along breaking waves at night. The writer remembers well that upon coming out of the water after a dip in the ocean at night, in the surf off the east coast of Florida, one's bathing suit was gemmed with bits of pale white fire, from the small phosphorescent jelly fish clinging to it. Among the most brilliant and conspicuous of all phosphorescent creatures, indeed, are the *Pelagia noctiluca* and *P. phosphora* and their unearthly blue radiance can often be recognized from the deck of a ship in mid ocean.

The umbrella varies a good deal in shape, being usually flattened and disk like, but sometimes conical, cubical or almost globular.

The large jelly fishes usually have a shape not unlike that of a mushroom. In some species there is a horizontal mem-

SPECIMEN OF NUDIBRANCH—SO CALLED FROM THE NAKED GILLS ON BACK AND SIDES

brane called the velum or veil, extending around the inner circumference of the disk.

In some species of these large jelly fish the stinging cells are so powerful that they have been compared with an electric battery. When the nettle-like threads contained in the poison cells succeed in penetrating the flesh of a man they are said to produce a sensation like that from an electric shock; the jelly fish employs this weapon to benumb its prey. It is even believed that some deaths by drowning have been caused by

a swimmer coming in contact with one of these big jelly fish and being paralyzed by the shock received.

The Rhizostomæ.—Among the most peculiar of the jelly fishes are those belonging to the sub order *rhizostomæ* (literally root-mouthed). These have no tentacles, but covering the end of the simple organ or manubrium are certain oval appendages provided with numerous funnel-shaped orifices called suctorial mouths. This plurality of mouths is stated to be unique in the animal kingdom. The different species vary in diameter from 3 to 8 inches. A typical member of the group is the genus Cassiopeia; the accompanying illustration shows the *C. frondosa*. On the margin of its circular disk there are no tentacles, but there are 16 sense organs called tentaculosysts. The lower end of the manubrium (the central tube ending in the mouth), which in other jelly fishes is merely an open mouth, is closed by 8 arms which spring from it; these are much branched and the branches in turn have numerous appendages, some of which look like little polyps, and which have mouths surrounded by crowns of tentacles. While this jelly fish is able to swim freely it usually lies upon its back lazily spreading and closing its disk without changing its position whie its arms extending upward make it look like a bit of seaweed.

THE ANTHOZOA

While the third class of the coelenterates, the anthozoa or actino zoa includes the stony corals, the flexible corals and precious coral, we shall here confine ourselves chiefly to the other members of the class, the sea anemones and the sea pens.

The animals of this class are divided into sub classes from differences in their anatomy. In the first, which includes the sea-anemones and the reef-building corals, the polyps have numerous simple hollow tentacles and the same number of raidal partitions, both being some multiple of six. Since this multiple of six is found in the arrangement of many flowers it suggests one reason for the resemblance of these fauna to many of our most attractive flora. The polyps of a colony are all alike and they all secrete carbonate of lime.

The Alcyonaria, or Halcyonoids.—In this second subdivision the tentacles and partitions are always eight in number, and the tentacles have small symmetrically-arranged branches. The hard secretions are horn and elastic, as in sea-fans, sea-whips, and sea-pens, or else extremely hard as in *Corallman rubrum*.

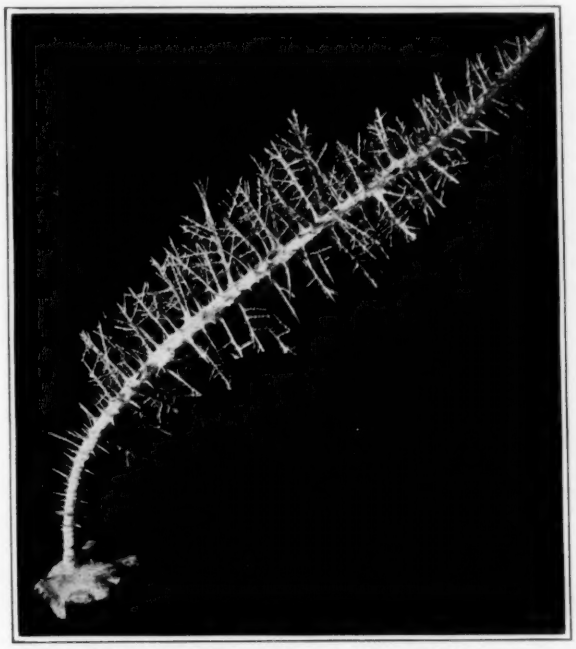
In the first class the sea-anemones belong to the order Actinaria in the subclass koantharia (literally *animal flowers*). Strange to say, while they strongly resemble flowers when expanded they do not resemble anemones. They vary greatly in color and form and are found in various parts of the globe, being largest and most brilliantly colored in tropical waters. Most of them are attached to some object but are able to change their location at will. Some of them, particularly the *Adamsia palliata* furnish an example of commensalism or symbiotic life. This sea anemone lives on the back of shells (generally whelk shells) which are inhabited by hermit crabs.

Corals.—The limits of this article prevent us from going fully into the subject of the corals, beyond saying that they resemble the sea anemone, being polyps constructed on the radial plan. They live in colonies, but unlike the hydroid colonies, each polyp is a complete organism and in the reef building corals all the individuals are alike.

Actinoid Corals.—In the alcyonaria or actinoid corals there are two kinds of polyps; the smaller have no tentacles and are called *siphono-zooids*, while the larger have only eight radial partitions and eight tentacles. Another characteristic of these polyps is the symmetrical arrangement of the branchlets on the tentacles. It is this arrangement which causes one of them to be known to fishermen as "dead men's fingers." Still another genus is the organ pipe coral or Tubipora which is a beautiful deep red in color and very frail, the many tubes of which it consists being slightly separated from one another but connected by horizontal platforms at short intervals. While the hard skeleton of the polyp is red the body of the animal itself is green, forming a striking contrast.

The sea-fans, sea-whips, sea-feathers present great variety of form and color. They grow in abundance on the coral reefs and mud flats of Florida, forming yellow-brown or purple masses resembling shrubbery.

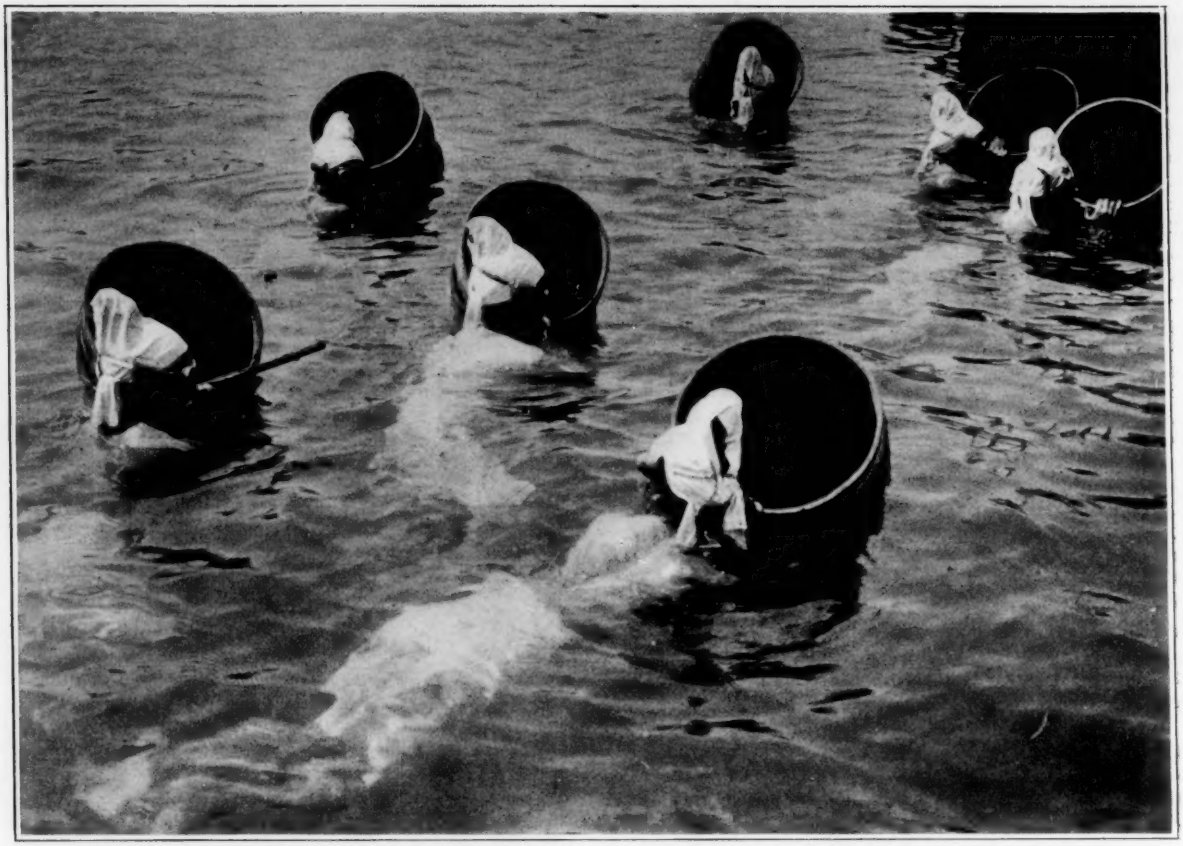
The Ctenophora.—These animals are known as comb jellies from the rows of flat cilia arranged like the teeth of a comb in 8 meridians, upon their spherical transparent bodies. The waving cilia give them a lovely prismatic shimmer by day, while at night they are phosphorescent. They differ from the jelly fish in their locomotion which is accomplished by means of the cilia. These operate like little paddles; they can be worked in unison, in single lines, or quite independently of each other, and for this reason the motion of the animal is very various and peculiar in character. A very curious feature in the comb jellies is the circulatory system through which they obtain both food and air; the mouth of the animal opens into a gullet which extends through ⅔ the length of the body.



NOT A SPRIG OF CEDAR BUT A LITTLE ANIMAL WITH A LONG NAME: *WALTERIA EUCKHARDI IJUMA*

On each side of the gullet is a vertical tube; these tubes unite at the base of the gullet and run from there as a single channel to the end opposite the mouth, opening to the outside through two excretory pores. From the base of the gullet where the tubes unite, two other tubes extend in a lateral direction; these divide and subdivide in a horizontal plane becoming eight in number; they connect at the surface with the lines of cilia and then divide and run in opposite directions to the two poles of the spherical body. At the pole opposite the mouth there is a nervous system located in a small area surrounded by cilia and having in its center an eye-speck or lithocyst.

Venus's Girdle.—Among the strangest of the comb jellies is the flat, narrow ribbon-like creature known as Venus's girdle, *Cestum veneris*, which is sometimes 4 or 5 feet long, though only an inch or two wide. The mouth is in the middle of the length, opposite the sense organ or eye spot. On each side of the mouth is a short tentacle. This animal moves more by means of contractions of its body than by the delicate combs which fringe its edges. It is very transparent, and of a delicate violet color. It is found in the Mediterranean Sea.



JAPANESE DIVING GIRLS AT WORK AT THE PEARL OYSTER BEDS

Artificially Induced Pearls*

A New Method of Producing Pearls Developed in Japan

By Dr. H. Lyster Jameson

ON May 4 a London evening paper announced that quantities of artificially produced Japanese pearls, of perfectly spherical shape, but containing in their centers heads of mother-of-pearl, had found their way into the London market and had deceived experienced pearl merchants in Hatton Garden, who had bought and resold them as naturally produced gems. Since that date many inaccurate, misleading, and contradictory announcements have appeared in the daily papers, leaving the public, both lay and scientific, in some confusion. The following statement of the position, so far as it can be judged from the scientific point of view, may therefore be useful:

For some years Mr. K. Mikimoto, the pioneer in the application of scientific knowledge to the pearly oyster on a commercial scale, has been producing in Japan, and selling under the name of "Mikimoto pearls," pearls of this description. There was no secret about this. Mr. Mikimoto not only sold them as artificially produced pearls, but also published in one of his catalogues (No. 33) a short description and diagram explaining his process.

Ever since 1898 Mr. Mikimoto (who began his work in collaboration with the late Prof. K. Mitsukuri in 1890) has been marketing half-pearls or "blisters," pearly excrescences formed by inserting a mother-of-pearl bead between the body of the oyster and the shell, and allowing the oyster to coat it over with nacre. This was, of course, merely a development of the very old operation by which the Chinese produce, in fresh-water mussels, the well-known mother-of-pearl images of Buddha, and of Linnæus's classical experiments in the eighteenth century. These products were known as "culture pearls," and have long been familiar in this country, set in brooches, tie-pins, rings, etc. Their value, compared with real pearls of corresponding sizes, was, of course, quite small.

For many years Mr. Mikimoto experimented with a view to the production of a complete pearl, not attached to the shell, by a modification of this process, and obtained his first successful results about 1912, as announced by me at the Dundee meeting of the British Association in that year. From information supplied to me by Mr. K. Ikeda, one of Mr. Mikimoto's staff, in a letter from Tokyo dated May 30, 1914, it appears that the first considerable crop of these "round cultivated pearls" was harvested in the autumn of 1913. Their production is now an important part of the original Japanese industry.

Apart from the purely financial question as to the degree to which the advent of artificially induced pearls is likely to affect the price of natural pearls, two questions seem to have been agitating the public: Are these products "pearls?" and can a test be devised by which, without destroying them, they can be distinguished from pearls of natural origin?

Of course, when a slice is cut across a natural pearl and a Mikimoto pearl the distinction is obvious. A natural pearl, except in those (in my experience exceptional) cases where a nucleus of foreign origin and of sufficient size to be identified

*From *Nature* (London), May 26, 1921, pp. 396-398.

(such as a grain of sand) is present, consists throughout of concentrically deposited layers, which differ in degree of transparency or opacity in different specimens (Fig. 1). The Mikimoto pearl, in its outer layers, has the same structure as the natural pearl, but has an artificially manufactured bead

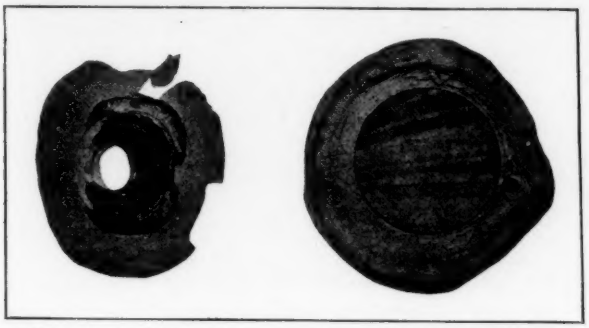


FIG. 1. SECTION THROUGH THE CENTER OF A NATURAL PEARL, X 6½. (ORDINARY LIGHT.)

FIG. 2. SECTION THROUGH THE CENTER OF A MIKIMOTO PEARL, X 6½. (ORDINARY LIGHT.)

Preparation and photos by M. A. Brammall

of mother-of-pearl, composed of flat parallel laminæ of nacre, in its center (Fig. 2). (These preparations and photos were made under the supervision of Mr. Brammall, to whose investigations reference is made below.)

The method by which Mr. Mikimoto produces these pearls has been patented by him in Japan and other countries, and an application for a British patent has already been filed, and is open for inspection at the Patent Office. The information here given was obtained from this specification, from a short description and figure published in one of Mr. Mikimoto's catalogues, and from facts supplied by Mr. Toranosuke Kato, his London representative. The process involves the most delicate and skilful manipulation, and it could be carried out, presumably, only by carefully selected and trained workers. The shell is removed from one pearl oyster, and a bead of nacre or other suitable nucleus is laid on the outer shell-secreting epidermis of the mantle. This epidermis, which is

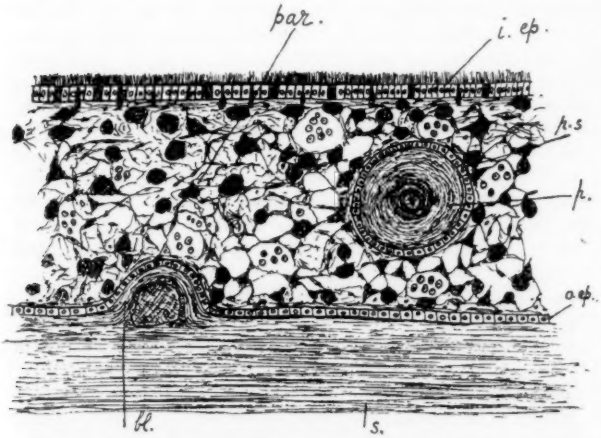
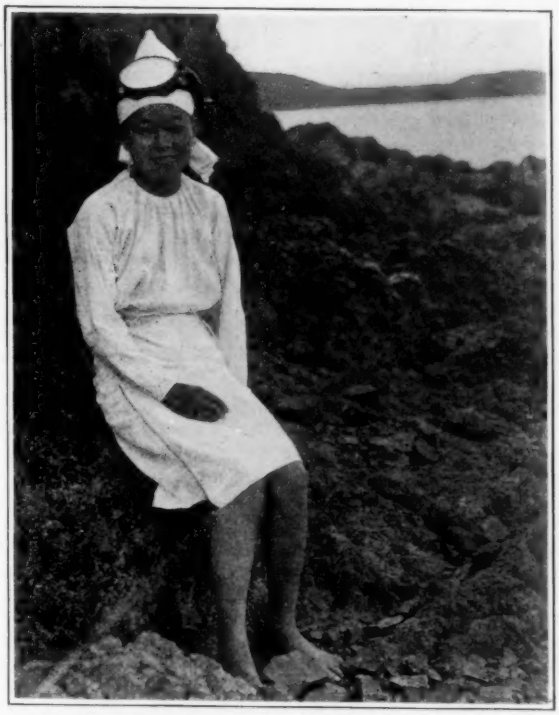


FIG. 3. DIAGRAM ILLUSTRATING THE DIFFERENCE BETWEEN A PEARL (*p.*) AND A BLISTER (*bl.*).

s., substance of shell; *o.ep.*, outer shell secreting epidermis; *p.s.*, pearl sac formed of shell-secreting epidermis; *i.ep.*, inner ciliated epidermis of mantle cavity; *par.*, parenchymatous connective tissue of mantle; *bl.*, blister; *p.*, pearl

composed of a single layer of cells of microscopic size, is then dissected off the oyster, and made to envelop the nucleus as a sac, the neck of which is ligatured. This sac is then transplanted into a second oyster and embedded in its sub-epidermal tissues, the ligature is removed, certain astringents or other reagents are applied to the wound, and the second oyster, with its grafted pearl sac containing the mother-of-pearl bead, is returned to the sea, where it has to remain for several years before a coating of pearl of sufficient thickness is secreted around the introduced bead. (In this letter of May 30, 1914, Mr. Ikeda stated that it took seven years.)

Now Mr. Mikimoto's success is based on the fact, which follows from my work in 1902,[1] and was further demonstrated by Alverdes's remarkable experiments ten years later,[2] that *it is not the presence of an irritating intrusive body that determines the formation of a pearl, but the presence in the sub-epidermal tissues of the oyster of a closed sac of the shell-secreting epidermis*, the secreting surface of which is not continuous with the secreting surface of the epidermis which lays down the shell; and that unless this epidermal sac is introduced by transplantation (as in Alverdes's and Mikimoto's methods), or is induced by the specific stimulation of a par-



A JAPANESE PEARL DIVER. NOTE THE LARGE GLASS LENS THAT IS DRAWN DOWN OVER THE EYES

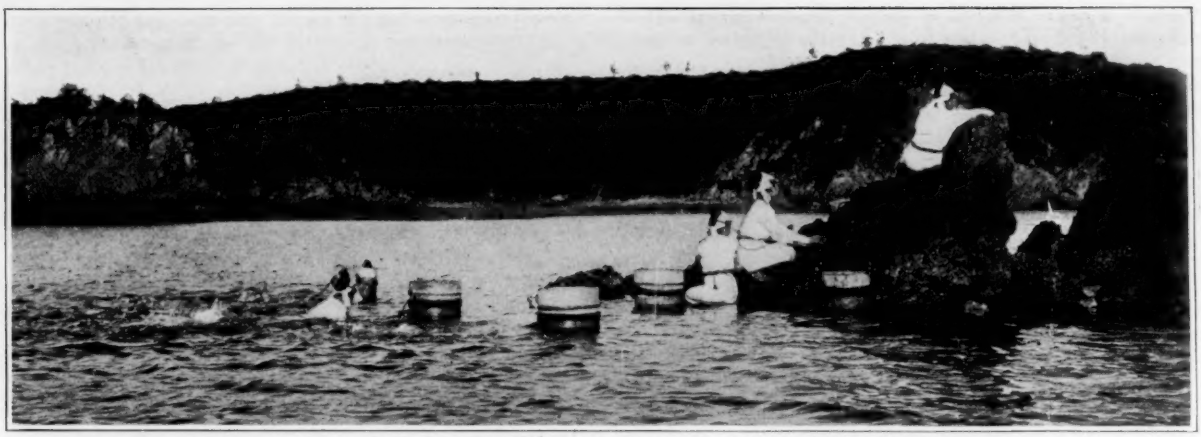
ticular kind of parasite (as in the pearls in Mytilus caused by the trematode Gymnophallus), or arises by some still unknown cause or causes (as in the Ceylon pearl oyster), no irritating body introduced into the shell or tissues can be expected to become the nucleus of a pearl. In my 1912 paper[3] I showed that the vast majority of pearls from the true pearl and mother-of-pearl oysters have no recognizable nuclei of foreign origin, the bodies so often taken for such, like the dark portion of the pearl shown in Fig. 1, and the center of the pearl diagrammatically shown in Fig. 3, being composed of a kind of shell substance of pathological origin, identical with that with which the oyster repairs an injury to its shell.[4] On the other hand, some of the natural pearls I have examined contained foreign bodies which (apart from the special case of

[1] Jameson, Proceedings of the Zoological Society, 1902, Vol. I, pp. 140-166, and *Nature*, January 22, 1903, p. 280.

[2] F. Alverdes, "Versüche über die künstiche Erzeugung von Mantelperlen ber Susswassermuscheln," *Zool. Anzeiger*, Vol. XLII., No. 10, 1913, pp. 441-458.

[3] Jameson, Proceedings of the Zoological Society, 1912, pp. 260-358.

[4] It is astonishing how the "foreign nucleus" theory of pearl formation sticks, as witness the utterances of scientific men of standing which have been called forth by the recent announcement.



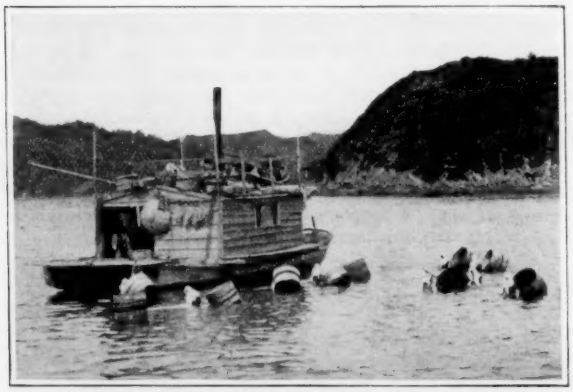
THE MIKIMOTO PEARL BEDS WHERE ARTIFICIALLY-INDUCED PEARLS ARE GROWN

the trematode which causes pearl sacs to form in Mytilus) ranged from diatoms and fragments of radiolarian shells and sponge spicules to quartz grains measuring, in one case, as much as 0.8 mm. in diameter. I propose to outline a theory attempting to account for the presence of these bodies in a later paper.

From the biological aspect there are two classes of pearly bodies. For the first of these, to distinguish them from true pearls, I adopted the name "blisters," familiar to pearl fishers, in 1902. Blisters (Fig. 3, *bl.*) are excrescences on the interior of the shell formed to close holes made by shell-boring animals, or to coat over intrusive objects such as grains of sand, small crabs, Fierasfer, etc., and in the case of the Buddha "pearls," Linnæus's "pearls," and the "half pearls" originally produced by Mr. Mikimoto, metal images or beads. Over such a blister the epidermis forms a little pocket directly continuous with the shell-secreting epithelium. A pearl, on the other hand (Fig. 3, *p.*), is formed in a closed sac of shell-secreting epidermis, which is embedded in the tissues of the oyster, and the nacre-secreting surface of which is not continuous with that of the epidermis that lays down the shell itself. A blister is a more or less hemispherical body passing over on all sides into the shell substance; a pearl is a concentrically deposited body, the substance of which is nowhere continuous with that of the shell. A pearl may, in the course of time, be ejected into the space between mantle and shell, and become more or less buried in the shell, forming the core of a blister; but in that case it can be dissected out from the shell layers deposited over it.

The trade distinguishes different kind of pearls according to shape and size (fine pearls, baroque pearls, seed pearls, etc.), just as biologists distinguish certain classes according to where they arise (parenchyma or mantle pearls, muscle pearls), or to the kind of shell material of which they are composed (nacreous pearls, columnar pearls, hypostracum pearls, periostracum pearls, hinge pearls). All these classes, some valuable, some worthless, are, from the biological point of view, *pearls*. Biologically speaking, the Mikimoto pearl satisfies all the conditions which go to make up a pearl as defined above. It differs from a natural pearl only in that it contains a foreign nucleus larger than any foreign nucleus which I have so far encountered in a natural pearl, and in that this nucleus is a bead of mother-of-pearl such as does not occur in Nature. Both these points could easily be remedied. A smaller nucleus could be introduced; or the nucleus might be removed after grafting the sac in the oyster; or a small natural pearl of inferior quality, or a concentrically bead of carbonate of lime, could be used as a nucleus. A trade in the worthless pearls of Mytilus might even be revived for this purpose; according to Garner they were once exported from this country to China for the manufacture of "medicine." The somewhat greater transparency, on the average, of Mikimoto pearls, when compared with natural pearls, could be remedied by either of these processes.

With regard to the question of distinguishing the Mikimoto pearl without cutting it, much vague talk as to scientific investigations has appeared in the daily press. Some of these investigations remind me of the little boy who, having learned that trains were propelled by steam, lighted a fire in his go-cart, put a kettle on it, and expected it to run by itself. Undoubtedly experienced pearl merchants, and, indeed, any zoologist who is familiar with the shells of the different species and geographical faces of pearl and mother-of-pearl oysters, can usually distinguish pearls from the Japanese pearl oyster (*Margaritifera Martensii*) from the pearls of other species, just as they can distinguish Ceylon, Australian, Central



WOMEN DIVERS LEAVING THE PEARL BOAT

A STATION WHERE THE PEARLS ARE SORTED

American, etc., pearls from each other by slight differences in color and luster; but this test only reveals that the pearls come from the Japanese pearl oyster, and cannot be used to distinguish naturally and artificially produced Japanese pearls from each other; and it would be useless for distinguishing pearls produced by the Japanese process in other species of pearl oyster from pearls naturally produced by the same species.

This natural difference is greatly intensified when the pearls are examined in ultra-violet light, for which purpose an apparatus has been designed and is already on the market. I hope shortly to be able to examine some naturally produced Japanese pearls with this apparatus. I anticipate that they will agree with the artificially produced Japanese pearls, and not with natural pearls from other localities, as this test, like the rule-of-thumb test based on the general color and luster, appears to depend on the minute differences in the structure of the nacre in different species and races of pearl oysters.

Immediately after the first announcement of the presence of these pearls in the market was made, I suggested to a press representative who called upon me that polarized light was the most hopeful line along which to seek a test that would reveal the presence of the artificial nucleus, and this suggestion was published in one of the daily papers on May 5. Immediately afterward I got into communication with Mr. A. Brammall, of the Imperial College of Science and Technology, South Kensington, who has since been engaged upon experiments which aim at determining whether polarized light can be applied to whole pearls in such a way as to furnish a test.

The behavior of polarized light when passed through *sections* of the natural and the Mikimoto pearl, respectively, was a foregone conclusion from our knowledge of the structure of their centers. When examined with polarized light between crossed Nicols, the section of a natural pearl, of course, shows throughout the cross of extinction characteristic of concentrically crystallized bodies (except in those parts which are too opaque to transmit light). A section of a Mikimoto pearl, on the other hand, shows the four arms of the cross in the outer part, which is concentrically laid down; but the mother-of-pearl bead appears alternately dark and light as the slide is rotated, according as the part of the exterior to which its laminæ are parallel is in a dark or a light sector. Mr. Brammall is not yet in a position to make a definite statement as to the practicability or otherwise of applying some modification of this process to the whole pearl. He will, of course, publish his results as soon as they are completed.

However, whether or not the pearls, produced by the Mikimoto process, which are now on the market, can be distinguished from naturally produced pearls, without destroying them, by virtue of their containing a large bead of mother-of-pearl, which behaves differently toward polarized light or toward some other variety of light, Mr. Mikimoto can easily remedy this in future by a modification of his process, such, for example, as one of those suggested above. That being so, and having in view the fact that, in the appropriate localities, "Oriental," Australian, Central American, and other varieties of pearls could be produced by the same process, it is probable that, as time goes on, more and more of the pearls coming into the market will have been produced, not by the old-fashioned methods of fishing for the "wild" pearl oyster, some of which methods have existed almost unchanged from time immemorial, but by such applications of scientific knowledge to cultivated pearl oysters as that in which Japan has given so conspicuous a lead.

Crystals, Solids and Vitreous Matter*

Basic Principles and General Phenomena Relating to Changes of Form in Matter

By A. Portevin

MATTER exists in two distinct states: amorphous and crystalline.

1. In the *amorphous* state the properties exhibited (electrical, optical, mechanical, etc.), are identical in all directions around each point, and no sign of orientation is to be found no matter what the process of examination employed—in other words, the matter is *isotropic*. Examples of amorphous bodies are fluids whether liquids or gaseous, gelatine and glasses.

2. The *crystalline state* on the contrary, is characterized by clearly marked differences as regards some or all of the properties exhibited, according to the direction; in other words, the matter is *anisotropic*. (In order to be complete it is necessary to add two other sorts of anistropy outside the general case of the crystalline state, namely, the anisotropic liquid drops described by O. Lehmann and the helicoidal structures discovered by Wallerant.) In a crystal of quartz, orcalcite for example, the properties are in function of the direction and within a single direction in space they undergo a change if the crystal be revolved; they thus define the *orientation* of the crystal.

In the case of transparent bodies the best method of revealing isotropy or anisotropy, *i.e.*, of determining whether the substance is amorphous or crystalline, is to examine the optical properties by means of polarized light. Such an examination is made by observing in a polarizing microscope thin slices of the substance in question.

Crystalline matter is rarely composed of a single crystal, but is made up, instead, of the juxtaposition of crystals which differ in their orientation; familiar examples of this are furnished by marble or by a lump of sugar. These conglomerates of crystals are usually formed when fused matter is cooled; *i.e.*, when it has been previously heated in a liquid state or when it has been dissolved in a suitable liquid and then allowed to cool, or, finally, by concentrating the solution through evaporation.

EQUILIBRIUM TEMPERATURE OF CRYSTALLIZATION, AND SOLIDIFICATION OR FUSION

A single definite body, whether simple or compound is capable of coexisting in the two states, liquid-amorphous and solid-crystalline at a given temperature T_0. At this temperature the liquid and the crystals are in equilibrium, *i.e.*, they are capable of remaining indefinitely in contact or as a mixture; the proportions of the mixture remain invariable provided there is no external loss or gain of heat. . . . If such a mixture be heated the crystals pass into the liquid state, *i.e.*, the temperature of fusion; if heat be subtracted by allowing the mixture to cool, the liquid will pass into crystalline state, *i.e.*, the temperature of solidification and of crystallization of the given liquid.

At this equilibrium temperature matter in the two states possesses different physical properties such as specific heat, density, viscosity, etc., and as a consequence of this, the passage from the liquid to the crystalline state and inversely is accompanied by a sudden variation of properties: Heat is liberated and there is usually a reduction in volume; this discontinuity enables us to examine the phenomena of crystallization.

It is only necessary in fact to observe in the course of the cooling of previously fused matter, either the temperature in function of the time or any property, whatever, in function of the temperature, and to note the temperature at which the representative curve obtained presents a discontinuity indicat-

*Translated for the *Scientific American Monthly* from *La Revue de l'Ingénieur* (Paris), for April, 1921.

ing the passage into the crystalline solid state, in order to obtain the equilibrium temperature of solidification or crystallization.

PASSAGE FROM THE AMORPHOUS STATE TO THE CRYSTALLINE STATE

As we have said the liquid and crystalline states are capable of coexistence in equilibrium only at a single temperature. (We are here considering only simple bodies or definite compounds.) Above this temperature only the amorphous liquid state is stable; hence there will be a fusion of the crystals. Below this temperature, on the contrary, the amorphous matter tends to crystallize and inversely this is effected at a certain rate which varies with the temperature, being, of course, nil at the equilibrium temperature.

In accordance with the general laws which govern all the phenomena of chemical and physical transformation, this rate is high in proportion to the elevation of the temperature, and to the absolute distance of this temperature from the equilibrium temperature.

Above the equilibrium temperature these two factors act in the same direction, so that the rate increases very rapidly with the rise in temperature: as a matter of fact it is impossible to heat a substance much above the equilibrium temperature without causing it to pass into the amorphous liquid state.

Below the equilibrium temperature these two causes operate in an inverse direction: the rate of the passage from the amorphous state to the crystalline state increases at first in proportion as the temperature falls below the equilibrium temperature, then passes through a maximum point, after which it decreases until it becomes practically nil, when the absolute distance of the temperature from the equilibrium temperature is sufficiently remote.

Thus while it is difficult to pass beyond the equilibrium temperature without causing the fusion of the crystalline matter, on the other hand it very frequently happens that the liquid may be cooled below the equilibrium point without causing crystallization to commence: in this case the liquid is in the state of *super-fusion* and the greater the distance between the actual temperature and the equilibrium temperature the higher the degree of this super-fusion.

This super-fused liquid is outside of a state of equilibrium and it tends to pass into a crystalline state, this being sometimes induced by crystals or crystalline particles thrown into it and sometimes quite spontaneous.

In the latter case the crystallization begins with the appearance of points scattered through the amorphous mass which are known as centers of *crystallization* and starting from which the crystals develop and grow with a value which varies according to the temperature. But the spontaneous formation of these crystallization centers is itself dependent upon the temperature, so that in reality the act of crystallization is characterized by two factors, both of which are functions of the temperature (Tammann):

1. The faculty of spontaneous crystallization;
2. The rate of growth of the crystal.

EXTERNAL AND FINAL FORMS OF THE GROWTH OF CRYSTALLINE ELEMENTS

Each crystallization center forms the starting point for individual crystals. There are three principal classes of these as regarded by their external form:

1. Convex *regular crystals* (Fig. 1); these are geometrical solids bounded by plain surfaces and governed by the laws of crystalline symmetry with respect to the mutual orientation of the plane surfaces. An example of these is found among alloys by definite compounds and, frequently, by the salts which separate from their solution.

2. Dendrites are crystalline structures of branching form (Fig. 2); they result from a preponderance of growth along the direction of the crystalline axes. Their general aspect recalling that of a branching fir bough. Pure metals and the solid solutions which they form within alloys crystallize in this manner. The viscoscity of the medium exerts a great influence upon the formation of dendrites so that it is possible by increasing the viscosity of the liquid—*e.g.*, by the addition of colloids to pass from convex regular crystals to dendritic forms (as in the case of the alum cited by Osmond and Cartaud and in Baumann's experiment).

3. *Sphero-crystals.*—These are groups of crystals in the form of needles radiating from a common center of crystallization (Fig. 3). The ensemble forming a small mass which is almost spherical outside and is therefore called a sphero-

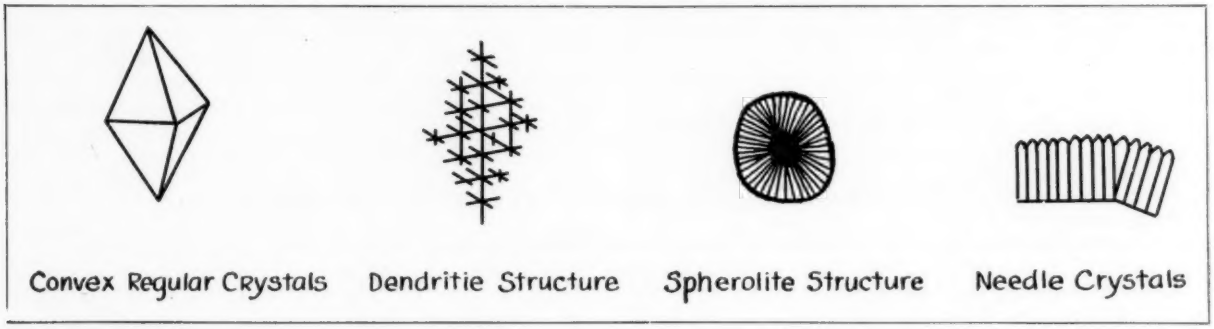


FIG. 1 FIG. 2 FIG. 3 FIG 4

light. The study of a great number of spherolites has shown that in reality they consist of helicoidal spirals; some bodies exhibit both simple spherolites and those marked by helicoidal spirals.

In all cases these various crystals dendrites and sphero-crystals develop from crystallization centers and cease growing by mutual limitation according to any sort of surfaces which bear no relation to the internal crystalline symmetry of the juxtaposed elements which form the whole. We thus finally obtain an aggregate of crystalline elements or grains, each grain being a crystalline individual or a spherolite, the *joints* of these grains being irregular surfaces which have no correspondence with the internal anisotropy of the elements of the structure (Allotrio-morphic crystals), whereas, during the free growth of the crystalline elements in the isotropic medium, the external forms bears a definite relation to the orientation and the crystalline symmetry—*i.e.*, with the anisotropy of the crystalline individual (Idio-morphic crystals).

As a general thing sphero-crystals are produced only when the degree of superfusion is rather strongly accentuated, and when the viscosity of the medium is, therefore, much increased; as a result of this sphero-crystals are never found in those metals and alloys which do not exhibit intensive degrees of super-fusion; on the other hand, organic compounds and silicates always have a tendency to form spherolites when super-fusion is very pronounced. (The addition of foreign substances may occasion at the time of crystallization the formation of spherolites marked by helicoidal spirals, the curve winding to the left or to the right according to whether the added substance is dextrogyrous or levogyrous according

to Wallerant.) It is even possible to observe, during the course of the cooling, polyhedric crystals at the beginning when the degree of super-fusion is slight, and then the formation at the surface of these crystals of filaments or "needles" which are normal to the facets which bound the crystal when the degree of super-fusion is most marked. (Fig. 4.)

Furthermore, it map be observed that the rapidity of growth, starting from a center of crystallization, is not strictly equal

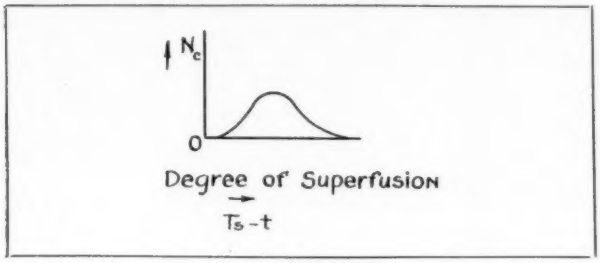


FIG. 5

in every direction, for in that case the external surface would form a perfect sphere. However, this condition is found in the sphero-crystals—the interesting form exhibited by silicates in a state of super-fusion. To simplify the discussion of the matter let us assume, as a primary approximation, that the rapidity of growth is independent of the direction, and we shall follow Tammann in calling this the *linear rapidity of crystallization.*

THE FACULTY OF SPONTANEOUS CRYSTALLIZATION—AMORPHOUS SOLIDS: GLASSES

When spontaneous crystallization occurs in a liquid which has been brought by cooling into a state of super-fusion, *i.e.*, to a temperature lower than the equilibrium temperature of the amorphous and crystalline states, there are produced, at isolated points of the mass, centers of crystallization, whose number increases in proportion to the duration of the said temperature; the power of spontaneous crystallization may be measured, therefore, by the number N_c of centers of crystallization formed in a given unit of volume during a given unit of time; this is termed by Tammann the *number of nuclei.* This number N_c which is one of the factors which determine the rate of the passage from the amorphous state to the crystalline state, varies with the temperature . . . in the following manner (Fig. 5): It increases with the degree of super-fusion, passes through a maximum and then in the case of higher degrees of super-fusion falls to zero—in other words, when the liquid has been brought to this point it loses its power of spontaneous crystallization.

In the case of those substances which readily undergo super-fusion it is possible by cooling them rapidly enough, starting from the liquid state, to bring them into a zone of temperature in which they will retain the amorphous state; in other words, they will undergo *no change of state* during the cooling process.

While the passage from the amorphous state to the crystalline state is accompanied by (and possibly revealed by) a liberation of heat during the cooling process, and a discontinuity in the variation of the physical properties with the temperature, we find, on the other hand, that if the amorphous state persists during the cooling process there is *merely a continuous variation of properties with no liberation of heat.* The viscosity alone varies in a manner which somewhat recalls a discontinuity; it undergoes, in fact, within a more or less narrow interval of temperature, a continuous but rapid increase, which causes the viscus liquid to yield finally a substance which is amorphous, non-fluid, resistant, and usually fragile—*this substance is a glass.*

Glass is a highly viscous liquid. Hence we see that glass is merely a liquid possessing a very high degree of viscosity; it is amorphous and, as a result of this, it is isotropic and inert to polarized light (that is in the absence of internal strains which occasion an irregular and transitory anisotropic, as we shall see later). The fracture of such a substance is smooth and conchoidal without any trace of grains or facets.

Inversely, if a glass be heated it becomes soft within a variable interval of temperature, and passes into the liquid-fluid state without its being possible to find upon the curve which indicates the heating process that discontinuity due to the absorption of heat, which accompanies the fusion of crystalline substances. *A glass, therefore, has no point of fusion, but merely an interval of softening* and in the same manner the cooling to the vitrious state of a liquid yields no definite point of solidification along the curve that indicates the cooling process. In the case of metals and alloys the temperatures of fusion and of solidification are determined by curves indicating the process of cooling or heating.

Such a process is inapplicable, on the contrary, for determining the solidifying temperature of a crystalline substance—such as silicate—which during the process of cooling passes into the vitreous state without crystallizing. In such a case all one can do is to determine the temperature of fusion by observing, during the process of heating, the passage from the crystalline state into the amorphous liquid state.

In brief, the cooling of a liquid may give rise to two kinds of phenomena (Fig. 6):

1. *The conservation of the amorphous state and the passage into the vitreous state with a continuous variation of the ensemble of physical properties.*

2. *The passage from the liquid and isotropic amorphous state into the solid and anisotropic crystalline state with discontinuity of the physical property, including viscosity, of course.*

In general the zone of devitrification lies very close to the zone of softening, since too great a viscosity of the medium tends to prevent crystallization.

LINEAR RATE OF CRYSTALLIZATION

The linear rate of crystallization V_c has been determined experimentally by Tammann in function of the temperature for various organic compounds; he places the super-fused substance in a U tube and observes the progress of the crystalli-

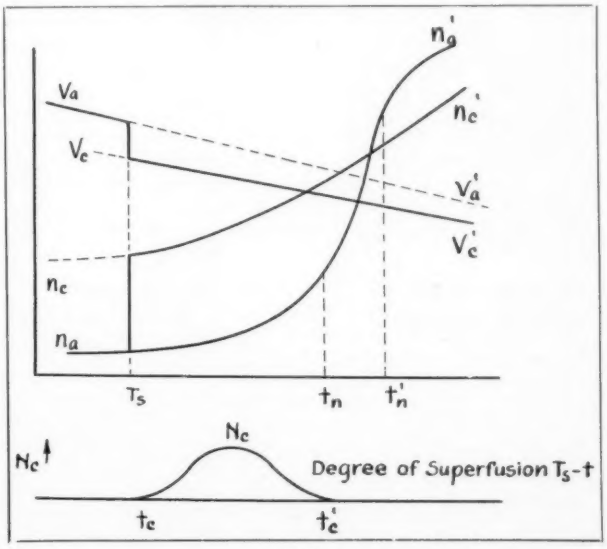


FIG. 6

zation within the tube by causing the super-fusion to cease at various temperatures by touching the free surface with a microscopic fragment of a crystal of the substance.

At the same time that the crystallization progresses the heat liberated tends to raise the temperature at the liquid-crystal contact, *i.e.*, at the limit of the crystallization. This elevation

of temperature depends upon the latent heat of fusion upon the specific heat, upon the calorific conductivity and also upon the speed of crystallization. If the maximum speed of crystallization is great and if it be found that in the area in which it decreases with the temperature the local elevation causes it to tend to increase and to cause it to attain the maximum, then in this case (great maximum speed of crystallization) the curve will not exhibit a maximum but an area of uniform maximum rate for a certain interval of temperature.

[*We are obliged to omit at this point a more or less technical discussion of the statements made, passing on to more general considerations.*—EDITOR.]

APTITUDE FOR THE FORMATION OF AMORPHOUS GLASSES—CAPACITY FOR SUPER-FUSION

It results from what has just been said that the conservation of the amorphous state consists in bringing the substance in question, without allowing it to crystallize, into the zone of temperature situated below that occupied by the curves giving N_c V_c in function of the temperature, the zone within which these two factors are practically nil. . . . The possibility of realizing this condition depends, in the first place, upon the rate of cooling, but likewise upon the values of N_c and V_c (the rate of crystallization as well as the ratio existing between these last two factors, *i.e.*, not merely upon their magnitude but also upon the relative position occupied by the curve representing their variations in function of the temperature.

Hence the aptitude for formation of an amorphous glass will be great in proportion as the maximum of N_c and V_c fail to appear simultaneously. . . . The capacity for super-fusion, in other words, the aptitude of a substance to enter the amorphous state in the course of cooling varies greatly in different substances. In simple bodies it is very slight in the case of those metals and alloys which are always in a crystalline state at any point below their point of fusion; in the case of metaloids such as boron, carbon, silicon, phosphorous, sulphur, arsenic, selenium and tellurium, they may be reduced to a pulverulent amorphous state so as to enable us to obtain glasses with sulphur and selenium. In the combinations formed with oxygen the metallic elements remain incapable of attaining an amorphous state; on the other hand the state of super-fusion is readily obtained with B_2O_3, S_i O_2, P_2O_5, As_2O_3 and this aptitude for super-fusion persists in the acid combination of these anhydrides with the metallic oxide. Certain ones among them exhibit a remarkable tendency toward the preservation of the amorphous state.

This is particularly true in the case of the silicates, the borates, and the phosphates; it is due to these properties of silicates that we are able to obtain industrial varieties of glass. The aptitude for super-fusion diminishes with the proportion of the basic oxides, so that the limits at which various silicious and boric glasses can be obtained are as follows:

Boric Glasses	*Silicious Glasses*
For an average rate of cooling	For a cooling period lasting half an hour and starting at 1000° cent.
$SiO_2 + K_2O$	$B_2O_3 + 1/6LiO_2$
$SiO_2 + 2/3Na_2O$	$B_2O_3 + 2/3ZnO$
$SiO_2 + 1/2CaO$	$B_2O_3 + 2/3CaO$
$SIO_2 + PbO$	$B_2O_3 + 2PbO$

With the rate of cooling mentioned above devitrification occurs as soon as the content of the base exceeds the limits given above. The silicate which then crystallizes is the monobasic silicate SiO_2MO.

SIZE OF THE GRAINS IN A CRYSTALLINE CONGLOMERATE

When the crystallization of the mass is complete a conglomerate of juxtapose elements is obtained resulting from the mutual limitation of the crystals of sphero-crystals which have developed starting from the centers of crystallization.

This mutual limitation results in the formation of structural elements whose external forms are approximately polyhedric and bear no relation to the internal anisotropy of the element; we have termed these grains whether they are crystalline *individuals* (convex crystals of dendrites) or radiating groups of acicular or filiform crystals (spherolites).

A grain corresponds to each center of crystallization formed after the disappearance of the amorphous state.

When these grains are all of approximately the same size their average size can be calculated provided we know the number of grains per unit of volume. The general method is to examine by the microscope a plane section of the ensemble, examining it by reflection in the case of an opaque substance and by transmitted light in a transparent or translucent substance, and then counting the number of grains visible in a given unit of surface, from which the number of grains per cubic meter can be readily found.

Small regular grains indicate high value N_c, the power of spontaneous crystallization, while irregular grains indicate low value of N_c.

The determination of the number of grains gives an idea of the magnitude of N_c but not its real value, since N_c represents the number of centers of crystallization per unit of time and per unit of volume of amorphous matter at a constant temperature. But these parameters change during the process of crystallization. Furthermore, the number of grains per unit of volume depends also upon the *rapidity* of crystallization, since this latter magnitude intervenes to determine the duration of the crystallization and by consequence the available time during which the centers of crystallization may be formed.

In case of metals and alloys the more rapid the cooling the finer the grain as a usual thing. This cannot be regarded as a general rule, however; *e.g.*, antimony acts in an exactly opposite way.

THE PROPERTIES OF MATTER IN A VITREOUS STATE

As we have already seen one of the characteristic properties of matter when in the vitreous state is that it exhibits no precise point of fusion as do crystalline substances, but on the contrary, a continuous variation of the viscosity with a rapid but progressive modification of this viscosity during an interval of temperature, known as the "softening interval." . . . This is a property of capital importance *from the point of view of the capacity for "working" of amorphous substances.* Since they are brittle at low temperature they cannot be worked by the ordinary methods of modeling, molding, drawing, or blowing except at temperatures at which they cease to be brittle without having yet become fluid.

The degree of the viscosity must vary according to the method in which the material is to be worked. Thus, it varies according to whether the operator is producing hollow bottles by a blowing process, wires or threads by traction, or still finer threads from which it is intended to form thicker threads (these thinner threads requiring a lesser degree of viscosity). Furthermore, the degree of viscosity must not undergo too rapid a modification with the temperature, since otherwise the work may be rendered very difficult and even practically impossible. . . .

The working of vitreous masses or even their cooling if the latter be too rapid, creates *internal tensions* which may persist or disappear when the surrounding temperature is reached. If they persist the glass is said to be *tempered*—but this term has not the same meaning as when applied to alloys. There is no change in the structure or constitution of temperate glass, but merely a lack of internal mechanical equilibrium, certain areas being subjected to tensile strains and others to compression strains which mutually balance each other. . . .

In pieces of glass having very high internal strains the slightest disturbance of equilibrium produced by a mechanical action, by a change of temperature, or by chemical corrosion, may cause it to break, sometimes with explosive force as in the case of Prince Rupert's tears.

In the case of transparent glasses these internal strains create an accidental double refraction, which may be shown by observation in polarized light between cross nicol prisms. . . . Sudden cooling does not cause persistent internal strains except when effected, starting at the minimum temperature at which the glass begins to be deformable under the most energetic strains which it can support without breaking. Below this temperature the internal strains produced during the cooling are temporary, ceasing as soon as all parts of the mass have regained the same temperature.

In his studies of industrial glasses (silicates and borates) Grenet has made the following observation:

1. *Softening Temperature.*—This is the temperature at which a vertical rod 1 cm. in diameter and 3 cm. in height softens under its own weight for about half its height: The load supported by the base of the standard glass prism is about 10 gr. per dq. cm. Industrially, this is the normal temperature for glass blowing and for glazing china; it also corresponds to the so-called fusion point in "Seger matches."

2. *Temperature of Rapid Annealing.*—This is the temperature at which the accidental double refraction disappears through the process of heating. . . . It is almost independent of the thickness of the specimen but is influenced by the rate of the heating. Industrially this temperature is that of the annealing of glasses and of the spreading of window glass.

3. *Temperature of Minimum Tempering.*—This is the temperature starting from which glass cooled rapidly ceases to acquire internal strains. . . by operating at a gradually increasing temperature we arrive at one where no temper can be observed and at another at which we perceive temper; the temperature of the tempering process is included between these two consecutive observations. These temperatures naturally depend upon the chemical composition.

In general the temperatures for annealing and for tempering determined by Grenet are very close to each other, the separation nearly always being less than 1000° cent. It is within this interval that the process of annealing must be conducted with extreme slowness.

OTHER FACTORS AFFECTING DEVITRIFICATION

We shall now attempt to show the double influence exerted, first:

1. By certain substances upon the rate of spontaneous crystallization, *i.e.*, the rate of devitrification;

2. The previous thermic history upon the power of spontaneous crystalization, in other words, upon the capacity for super-fusion.

Influence of Catalyzers.—If, starting from silica glass we desire to obtain crystalline silica in the form of tridymite, heating alone will not suffice; we must make use of alkaline chlorides as catalyzers or "mineralizers." The same thing is true when we desire to transform the same silica glass into quartz, which is another crystalline form of silica.

On the other hand heat alone will enable us to devitrify silica glass into crystobalite, another crystallin form of silica, provided the temperature is right, but in this case likewise the rate of devitrification depends upon the purity of the vitreous silica.

The classic researches of Ebelmen, Hautefeuille, Deville and Caron, etc., with respect to the synthesis of minerals have thrown much light upon the part played by the so-called mineralizers (borates, phosphates, carbonates, fluorides, tungstates, vanadates, chlorides, etc.).

Influence of Anterior Thermic History.—When you wish to obtain a super-fused liquid it does not suffice merely to melt the body at its fusion temperature; it is also necessary in general to heat the liquid obtained for a considerable length of time, and even to raise it to a temperature higher than that of fusion. The temperatures employed and the periods of duration of the process of heating in the liquid state react upon the capacity for super-fusion. This has been explained by assuming the persistence in the liquid of germs or particles, in other words of crystalline nuclei or starting points, which, during the process of cooling form around pre-existent centers of crystallization and which disappear only very gradually under the prolonged influence of heat in the liquid state.

As we have seen the number and size of the grains after devitrification are a function of the number of centers of crystallization formed in the amorphous medium. It results from this that the number and size of the grains may depend upon the given temperatures and durations of heating in the liquid state and also upon the number of fusions undergone by the substance—in a word the size of the grains depends upon the thermic history previous to the latest crystallization. Thus Carpenter and Edwards found that the size of the grain in certain aluminum bronzes augmented progressively in the course of the series of alternate fusions and solidifications. . . . We may cite also the influence of the casting temperature upon the size of the grains in solidified crude metals and alloys. To sum the matter up we may say that the maximum heating temperature, the duration of the heating, and the number of repeated fusions modify the capacity of superfusion and the aptitude for devitrification, and that these operations should be considered by industrial operators.

AMMONIA BY THE HYPER-PRESSURE METHOD

THIS note on the present status of the synthesis of ammonia by the hyper-pressure method is taken from the April 20th number of *Chemical and Metallurgical Engineering:*

"At the February 21, 1921, meeting of the French Academy of Sciences, Georges Claude presented a note on the present status of the synthesis of ammonia by the hyper-pressure method. The first practical demonstration of the process before a number of members of the Academy took place January 9, 1920, when the mixture $N_2 + 3H_2$ was first compressed to 100 atmospheres by an ordinary compressor of 60 cu. m. per hour capacity and then compressed by two hyper-compressors in series to 300 and 1,000 atm. The hyper-compressed mixture after it had been purified was passed through a catalyzer tube giving from 6 to 7 liters of liquid ammonia per hour. All the apparatus had to be placed in wells and the manipulations were difficult.

"The second demonstration took place November 20, 1920. At this time there were four catalyzing tubes instead of one. The tubes were arranged two in parallel and the other two in series and sufficient for the combination of 80 per cent of the gases treated. The tubes were placed in separate compartments located in a building on the ground. The same hyper-compressors were used as during the first demonstration, but were operated to produce 150 cu.m. per hour instead of 60. All the installation proved to be perfectly gas tight, as there was no trace of ammonia odor in the building. The production was 60 to 70 liters of liquid ammonia per hour—*i.e.*, about 1.25 tons per day.

"At the present time a great step in the process has already been realized—namely, the production by a single hyper-compressor of the two stages 100 to 300 atm. and 300 to 900 atm., which is the final pressure used. This hyper-compressor has been made by M. Le Rouge and compresses 700 cu.m. of the mixture per hour, a quantity sufficient to give 5 tons of anhydrous ammonia per day, equivalent to 25 tons of ammonium sulphate per day. The energy consumed for the compression of 710 cu.m. from 1 to 100 atm. was 187 hp. and for the compression from 100 to 900 atm. 122 hp.—*i.e.*, about ½ hp-hr. is required to compress 1 cu.m. of the mixture to 900 atm. The tightness of the installation is such that under the hardest conditions of starting and stopping of the operations the loss of gas mixture was less than 0.5 per cent. One of the four catalyzing tubes of a capacity of 5 tons NH_3 per day was tested at the same time and found to work successfully.

"Since former tests showed that it is easy to have all four tubes working simultaneously, the application of the process to large industrial units seems certain to prove successful, provided an adequate cheap source of hydrogen can be found."

Producing Soap from Petroleum*

The Synthesis of Fatty Acids from Paraffin and Other Petroleum Fractions

By K. Loeffl

DURING the war the Germans paid considerable attention to the production of fatty acids by the conversion of the higher aliphatic hydrocarbons, mainly paraffin, into the aliphatic carboxyplic acids, or as they are commonly called, the fatty acids. The Aktiengesellschaft für Mineralindustrie, the Chemische Fabrik Treisdorf and the Deutsche Erdol-Aktiengeselischaft were the most prominent companies who worked on this problem (for further details see *Chemiker Zeitung*, 1920, pp. 309 and 477).

In the year 1884 a patent was taken out by Schaal, in which the fundamental principles of the process were stated. The conversion of the hydrocarbons, obtained by the distillation of anthracite coal, lignite, peat, oil shales, etc., was accomplished by treating them with a current of air or oxygen at atmospheric pressures or higher, either in the hot or the cold, in the presence of the caustic alkalies, the alkaline earths, the alkaline carbonates or any other substances, which give an alkaline reaction. The soaps obtained in this way were decomposed and the free fatty acids were recovered by fractional distillation or by extraction with petroleum or other solvents.

Although the patent was a basic one, nevertheless it was not a commercial success, because the yield was altogether too small. This was not the only fault with the process, for the product was contaminated with useless by-products, the removal of which entailed too much expense to be practical. Hence, all the efforts of the numerous workers in this field were directed toward the obtaining of an increased yield. To this end, attempts were made to develop catalysts which could be used for this purpose. According to the experience of the writer, none of these catalysts produced the required results.

The really important factors in the process are as follows: The temperature, the pressure, the tubes in which the process takes place, the duration of the treatment with oxygen, the presence of water, and the presence of alkalies.

Temperature.—This is of particular importance. Tests were made at various temperatures from 60 to 200 deg. cent. The greatest yield was obtained at 115 to 120 deg. cent.

Pressure.—Pressures of 1, 2, 3 atmospheres were used, and an experiment was carried out under a vacuum. The most advantageous pressure was found to be 3 atmospheres.

Reaction Tubes.—When soluble catalysts were used, it was developed that the use of tubes in the process increased the yield and shortened the time of the reaction by half.

Duration of Oxygen Treatment.—This is an important factor, as it was found that when a pressure of three atmospheres was used and the reaction carried out in good tubes, the same yield was obtained after seven hours' treatment with oxygen, as in the experiment wherein the duration of the introduction of the gas lasted 78 hours. Furthermore, the product was considered lighter in color and less resinified.

Presence of Water.—The presence of water is essential to the success of the process. When the reaction is allowed to proceed without the addition of water, or when the water that results in the oxidation is removed as soon as it is formed, a very low yield is obtained. The product of the oxidation is much darker in color, and contains considerable quantities of polymerized dark colored products, even when the reaction takes place at scarcely over 100 deg. cent.

Presence of Alkalies.—The presence of alkalies is not essential to the success of the process according to the findings of the writer.

The process of treating the product of the oxidation in order to recover the fatty acids contained therein consisted in subjecting it first to the action of superheated steam. The lower boiling fatty acids were driven off in this way. Then, another steam distillation was carried out under a vacuum in stills, such as are used generally in the rectification of glycerine. The nature of the crude product will determine how much of the high molecular weight fatty acids will be obtained on fractionation. A fatty acid melting at 68 deg. cent. was obtained from a particularly well fractionated and well washed raw product by recrystallization from a boiling alcohol-ether mixture.

The total yield was 98 to 120 per cent, on the average 106-110 per cent of the original material. Of these 110 parts 7 to 20 per cent is water, 25 to 40 per cent, a fraction boiling at 200 deg. cent. (lower boiling fatty acids mixed with aliphatic aldehydes and ketares) and the remainder, 78 to 50 per cent, a mixture of higher boiling fatty acids, which contains 10 to 15 per cent of unsaponifiable matter.

While the process has not been applied successfully on a commercial basis as yet, nevertheless it is the opinion of the writer who is the Director of the Technical Department of the Deutschen Erdoel Aktiengesellschaft, that it is possible to manufacture fatty acids on a large scale by this method. Such a product when mixed with 10 to 20 per cent fat, cocoanut and palm kernel fatty acids forms a mixture which is very satisfactory from the standpoint of color, odor and purity for the manufacture of soaps for all rough work.

*From *Chemiker Zeitung*, 1920, pp. 561-562.

METAL PROTECTIVE PAINTS

MR. H. A. GARDNER, before the American Electrochemical Society's annual meeting brought out that high grade metal protective paints are now produced on the following four principles:

"1. Basic substances in sufficient concentration inhibit the corrosion of iron. Basic pigments that are effective for this purpose are litharge, red lead, blue lead (basic lead sulphate), white lead, zinc oxide.

"2. Chromic compounds (soluble bichromates), even in great dilution, prevent the corrosion of iron. Chromate pigments that are similarly effective when used in sufficient amounts are as follows: Basic lead chromate, normal lead chromate, zinc chromate.

"3. Neutral substances that do not ionize to acid reaction are considered inert. So-called neutral or inert pigments, such as iron oxide, which do not excite corrosion, produce with linseed oil very durable films. Such pigments include black, brown and red oxides of iron, china clay, silica, talc, and barium sulphate.

"4. Substances that form a galvanic couple with steel in the presence of moisture cause rapid corrosion. Pigments which act in this fashion (graphite, carbon black, lampblack) are used only as constituents of the finishing coats on steel surfaces when first insulated from the metal by a coat of basic or chromate pigment paint. These carbon pigments with linseed oil form very durable and water-resisting coatings."

After discussing the primer paints and finishing paints Mr. Gardner concludes that the best principles for painting iron and steel involves the use of a primer coat containing basic or chromatic pigments and the finishing coat of red oxide or black carbon pigment. Where high light reflecting power is desired lighter tinted or even white finishing paints are employed. Titanium oxide is the only white opaque pigment that is insoluble in most acid gases. 25 per cent titanium oxide precipitated on 75 per cent barium sulphate possesses tremendous hiding power and is usually applied with up to 40 per cent zinc oxide to give satisfactory hardness.

Hydrogen from Steam—II

Commercial Processes Utilizing Steam in the Production of Hydrogen

By Harry L. Barnitz, Ph.G.

(Concluded from our July issue, page 63)

IN the last decade only three processes for large commercial production of hydrogen have been employed and these processes all utilize steam. They are known as the Iron Contact Process, Badische Process and the Linde-Frank-Caro process. In describing these processes the Iron Contact Process will first be considered.

The Iron Contact plant is commercially represented by two distinct types:

1. The Multiple Retort Type;
2. The Single Retort Shaft Type.

THE MULTIPLE RETORT TYPE

In the Multiple Retort Type[1] the furnace consists, primarily, of a brickwork casing (Fig. 3) containing thirty-six vertical, cast iron, pipe-like retorts. The top ends of the retorts are flanged and provided with covers for removal when the retorts have to be recharged with ferrous material. The spent material is removed through similar covers at the foot of the retorts. The thirty-six retorts are arranged in two groups, each containing two rows of nine retorts each. This division is of no practical significance. What is important is the division of the thirty-six retorts into three groups P, Q, R (Fig. 4), each group containing three of the retorts in each longitudinal row. While the groups P and Q are "reducing" the group R is "oxidizing." After running thus for a certain length of time, the group Q is changed over to "oxidizing" and the group R to "reducing," the group P remaining at the reducing setting. Thereafter P is set to oxidize and Q and R to reduce. In this way the generation of hydrogen—from the oxidizing group—is made intermittent, while the double time required for reducing is allowed to each group.

In order to facilitate the description, the three groups of retorts are, in the diagram of the plant given in Fig. 4, represented as three single retorts P, Q, R. Across the front of the furnace and external to the brickwork, there run six horizontal pipes A, B, C, D, E, F. The top end of the retort P is connected as at G to a valve H on the pipe A, and the bottom of the same retort as at J to a valve K on the pipe F. The top and bottom ends of the retort Q are similarly connected to valves on the pipes B, E, respectively, and the top and bottom ends of the retort R to valves on the pipes C, D. The three pipes A, B, C are connected at each end to vertical pipes L, M, and the three pipes D, E, F to two other vertical pipes N, S. The valves H, K are inter-connected so as to be operated together. The two other pairs are similarly connected.

The pipe N is connected with the water-gas supply. With the valve setting indicated in the diagram, the retorts P, Q are receiving water-gas from the left-hand portions of the pipes F, E, respectively. The gas rising up the retorts is reducing the ferrous oxide in them, and with the moisture and carbon dioxide, resulting from the reaction, is passing away by the left-hand portions of the pipes A, B to the pipe L. From this pipe it may be sent wholly into the furnace for heating the retorts.

The pipe M is connected with a supply of steam. With the valve setting represented in the diagram, the retort R is receiving steam from the right-hand portion of the pipe C. This steam passing downward becomes decomposed, oxidizing the metallic iron in the retort and setting free hydrogen. The hydrogen leaving the bottom of the retort reaches the right-hand portion of the pipe D and so passes into the pipe S, whence it is conducted to a purifying plant and a gasholder.

By the operation of two of the three connected pairs of valves, every ten minutes or so, the plant is capable of giving an intermittent output of hydrogen. Two practical points have, however, to be noted. In the first place, when any one of the retorts is changed over from "reducing" to "oxidizing," it is at the moment of the change filled with water-gas carrying a certain percentage of moisture and carbon dioxide. The first portion of hydrogen formed is contaminated with these substances. To avoid passing this impure gas into the pipe S, it is arranged that the valves, while they can be operated simultaneously in pairs, can also be operated separately. Thus, when the reducing period in, say, the retort P is completed, the valve H is operated to admit steam to the top of the retort, while the valve K is for the moment left untouched. The steam being at a higher pressure than the water-gas, passes down the retort and becomes converted to hydrogen. This hydrogen mixing with the water-gas in the retort causes the latter to flow back into the pipe F and the pipe N. The impure hydrogen then passes with the fresh water-gas into

[1]The multiple retort generator described is that of the Lane type.

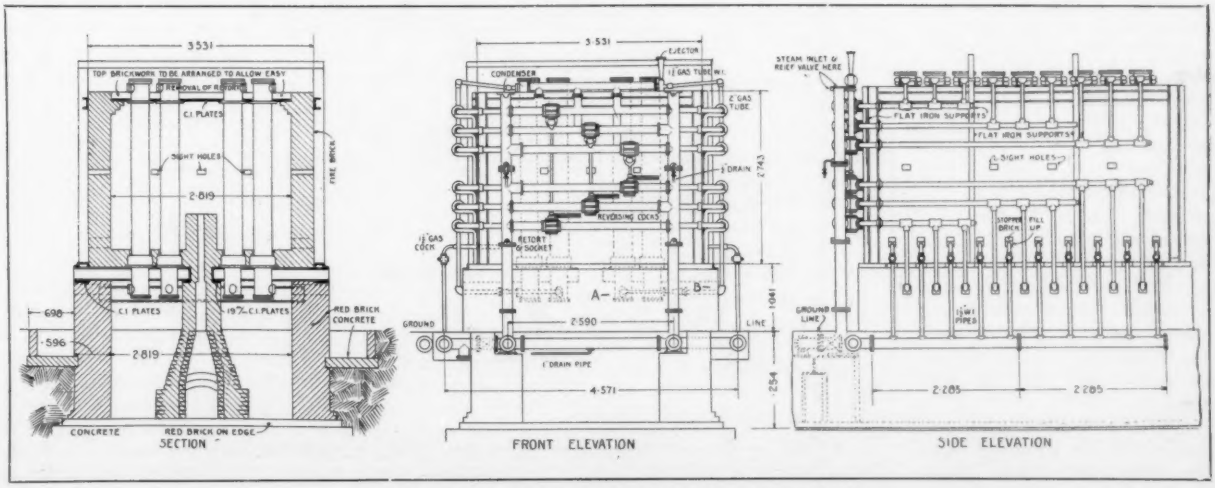


FIG. 3. A MULTIPLE RETORT HYDROGEN GENERATOR

the retort Q and the retort R—now set for reducing—and is therefore not wasted. In a short time the hydrogen generated is sufficiently pure to permit the valve K to be operated so as to allow the retort P to take up its proper function.

When passing from "oxidizing" to "reducing" the retort is

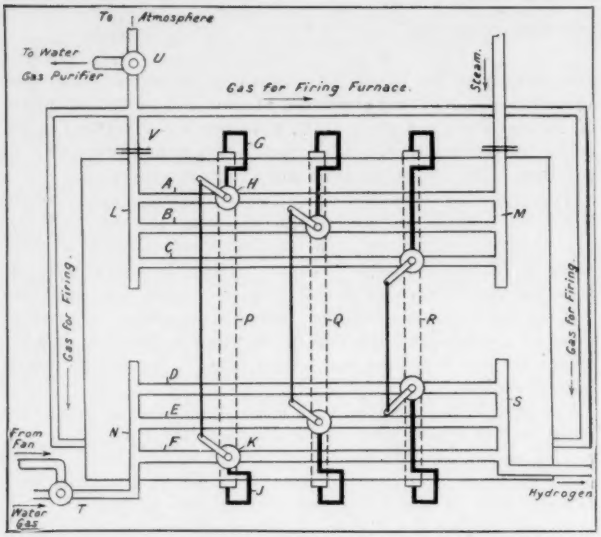


FIG. 4. DIAGRAMMATIC VIEW OF THE MULTIPLE RETORT GENERATOR

at first filled with pure hydrogen. The pair of valves can, therefore, be operated simultaneously when the change from oxidizing to reducing is being made.

As previously stated the ferrous material, unless revivified in some way, very soon loses its activity and fails to decompose the steam, owing to the deposition on the iron of sulphur and other impurities which accumulate in the retorts during successive periods of reduction. To partially overcome this trouble air is blown at intervals through the retorts, so as to burn out the accumulated impurities. To effect this, the three-way cock T (Fig. 4), is turned to shut down the supply of water-gas and to open a branch pipe leading from a fan or other blower. The three-way cock U on the excess water-gas outlet pipe is also turned so as to close this pipe and open a branch pipe leading from a fan or other blower. The three-way cock U on the excess water-gas outlet pipe is also turned so as to close this pipe and open a branch pipe leading to the atmosphere. The air from the fan, if the retort valves are placed in the "reducing" position, then passes up through the retorts, and with the sulphur dioxide and other products derived from the impurities in the ferrous material blows off into free space.

For efficient combustion that portion of the water-gas used for firing the furnace should not be heavily laden with moisture. Accordingly, somewhere at or near the point V (Fig. 4) the excess water-gas is taken off to a condenser and returned. The condensers are placed in the immediate vicinity of the furnaces (Fig. 5).

The retorts are of cast iron and are 9 inches in internal diameter, 1½ inches thick, and 9 feet 9 inches long. Each fits into a base socket and seats therein on a joint of asbestos. The three groups of retorts P, Q, R as shown in Fig. 3, are each divided into two equal subgroups. Six pipes—see the side elevation—run horizontally along the two sides of the furnace exterior. To each of these pipes the top or the bottom ends of a sub-group of the retorts are connected. Each of the six pipes on one side of the furnace is connected to the corresponding pipe on the other side by a horizontal pipe extending across the front of the furnace. This front pipe in each instance is interrupted at a suitable point to couple up with the two flanges of the reversing cock. The top ends of the twelve retorts in each group are thus connected to one such reversing cock, while the bottom ends of the same twelve retorts are connected to a second reversing cock situated directly in line with and below the first, as shown in the front elevation in Fig. 3. In front of the six front pipes referred to, and connected to the flanges H J of the reversing cocks, lie the six pipes represented in the diagram (Fig. 4) at A B F. The vertical pipes L M N S are clearly shown in Fig. 4, the only point to notice being that in practice the pipes L and M are respectively united to the pipes N and S, and are not separated therefrom. A blank is interposed between the flanges of each pair.

Three-way cock plugs turned anti-clockwise through about 30 deg. the ports are opened, and reducing gas is sent upward through the retorts. A 60 deg. movement of the plug in the clockwise direction from this position opens the ports and causes steam to pass downward through the retorts. A fourth and fifth port are formed in the body of the reversing cock, and when the cock is in the central position, these two ports are open to one another. The flange in each of the three lower reversing cocks is open to the atmosphere. In the three upper

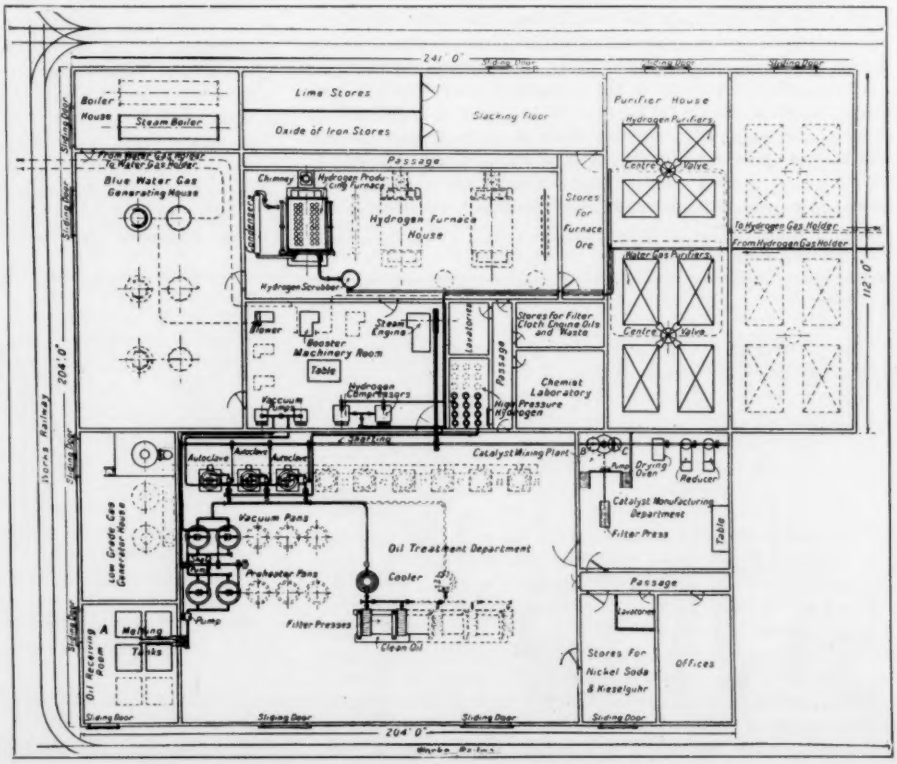


FIG. 5. GENERAL VIEW OF THE PLANT

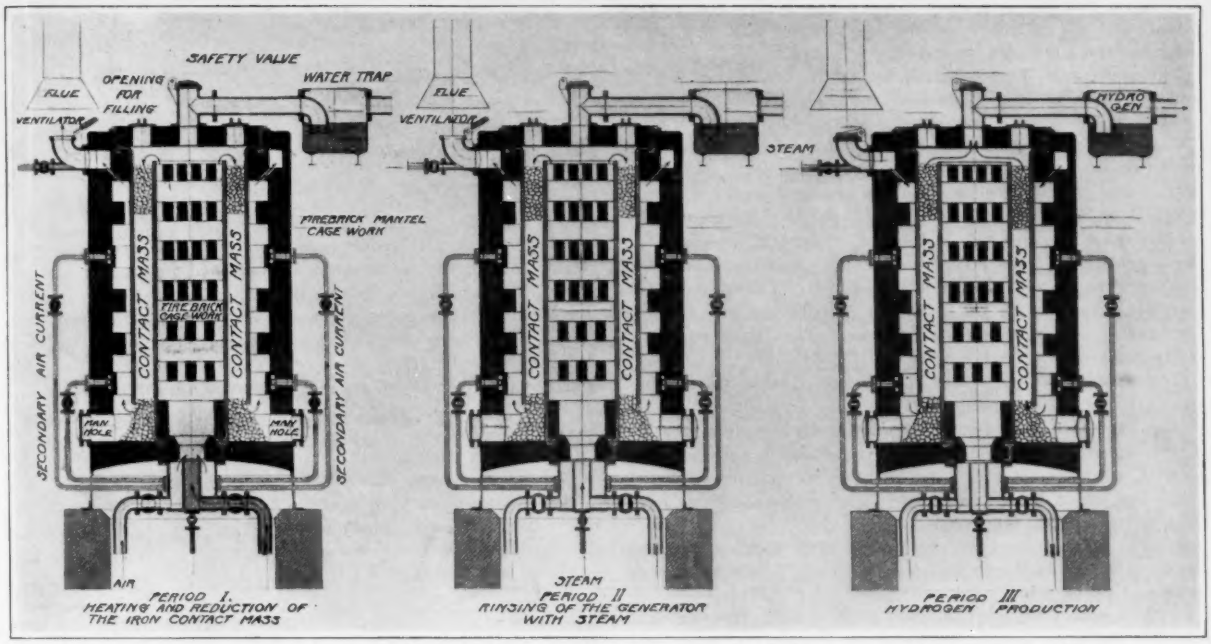


FIG. 6. THREE WORKING PERIODS OF THE LATEST TYPE OF MESSERSCHMITT HYDROGEN GENERATOR

cocks it is connected by a vertical pipe to a horizontal pipe extending across the top front edge of the furnace casing. At one end of this horizontal pipe an ejector is fitted. By turning the reversing cocks into the central position, and setting the ejector to work, air is drawn upward through the retorts for the purpose of burning out the impurities which accumulate on the ferrous material. The use of an ejector in this way instead of a fan as indicated in Fig. 4 is now the practice.

It will be noticed from the front elevation in Fig. 3 that the spindles of the three upper reversing cocks are extended down to the level of the lower cocks so that the handles of each pair are brought close together. The two cocks of each pair can thus be moved simultaneously as when passing from "oxidizing" to "reducing," or separately as when the impure hydrogen has to be blown momentarily into the water-gas pipes at the commencement of the oxidizing periods.

During the normal running of the furnace the excess water-gas is, as previously stated, made use of in part for firing the retorts. At the commencement of a run a valve near the reducing gas inlet is closed and another one on the same pipe is opened. This permits of firing the furnace with water-gas taken direct from the supply main. These means are also called into use during the slack periods, when the generation of hydrogen is interrupted. The firing may be reduced during such periods, but it is not desirable that it should be totally stopped. It is recommended that the plant should be run continuously day and night.

The plant illustrated in Fig. 5 has a rated capacity of about 3,500 cubic feet of hydrogen per hour.

THE SINGLE RETORT SHAFT TYPE

This type is represented in the Messerschmitt generator. The fundamental principles of the single-retort shaft-type hydrogen generator are, that the hydrogen is generated in a generator shaft with separate compartments for heat and contact mass, which are connected in such a way that heating, process of reduction, and generating of gas take place in the interior of one and the same apparatus.

Fig. 6 is a projective reproduction of the three working periods of a hydrogen generator of the Messerschmitt type, explaining the construction of the generator and its working methods.

In a generator shaft, lined with fire brick, two iron cylinders are built in, in a vertical position. The inner cylinder rests on the floor of the generator. Between these cylinders the iron contact mass is stored. In the interior of the inner smaller cylinder there is a cagework of fire brick which serves as storage of heat. The larger cylinder is also surrounded by fire brick cagework which is incorporated in the construction of the outside fire brick mantel of the generator. For the heating of the cagework, and for the heating and reduction of the contact mass, reducing gas (blue water) and air are introduced from underneath into the interior part of the generator, the air being in such volume as not to be sufficient for complete combustion of the heating and reducing gas (blue water-gas).

The combustion and the parts of the gas not consumed rise upward in the inner cagework, pass through the contact mass downward into the outer cagework where the rest of the gas is consumed by an additional or secondary air current, rising again upward to pass through the flue into the open. The heat is thereby imparted to the cagework, at the same time heating and reducing the contact mass. The duration of this heating and reduction process is about 20 minutes. After this the supply of heat, reduction gas and air is shut off and steam is introduced from underneath into the generator.

The steam and the carbon dioxide generated from the contact mass are driven out through the flues.

As soon as hydrogen escapes with the steam, which can be easily detected by the forming flame, the supply of gas and air is discontinued, and at the same time the ventilator leading to the flue is closed. The so-called rinsing or steaming period now begins, which requires only a few seconds, steam being passed through the apparatus as shown in the second diagram.

Then the third period begins. Steam is passed from above into the outer cagework of the generator, and the actual hydrogen production period begins. The steam coming into contact with the glowing contact mass which is now reduced, is decomposed and hydrogen is liberated with the formation of iron oxide. The outflow of the generated hydrogen takes place on the top from the center of the generator into a chamber with a water trap. From there the hydrogen passes

through a purifier into the hydrogen gas holder and is then compressed in cylinders or storage tanks. The gas period is of about 15 minutes' duration.

The process is then repeated by again introducing heating and reduction gases and air into the generator. The working method is therefore a periodical one.

The great amount of heat required during the heating and reduction periods is imparted to the contact mass and stored in the fire brick cagework. During the gas period this heat is taken up, the fire brick cagework imparting its heat to the contact mass; besides, the introduced steam which passes over the cagework becomes highly superheated and the most effective temperature for reaction is reached. The proper temperature required for this process is between 700 and 800 deg. cent., as was mentioned before. This temperature is easily reached in this generator.

Overheating, which would impair the life of the contact mass and the other materials is avoided. By the construction of the hydrogen generator of this type a even temperature of the contact mass is more readily obtained without overheating, while the required temperature is quickly imparted.

A. The generator is readily put into action, and the heating requires only a few hours.

B. The arrangement of the heating and contact compartments of this generator exclude all possibility of the hydrogens, being lost or escaping.

C. The generator gives off very little heat to its surroundings, the fire brick forming an excellent insulator of heat. The workmen are therefore not troubled by heat or gases. One man can easily attend two hydrogen generators—his whole duty is to change levers for each working period and read the pyrometer. All lever positions are automatically locked, thus preventing a wrong position of ventilators.

To replace the contact mass after long use, openings for fillings are arranged on the top of the generator, and to remove it, Morton doors are placed on the lower part of the generator mantel. One coke generator and one steam boiler are sufficient for several hydrogen generators.

Theoretically, to produce 1,000 cubic feet of hydrogen at 30 inches barometric pressure and 40 deg. fahr. 116.5 lbs. of iron and 49.95 lbs. of steam are required. In practice these figures are not closely approached, the magnetic oxide of iron formed tends to shield the metallic iron from the action of the steam. In practice, to obtain a yield of 3,500 cubic feet of hydrogen per hour, approximately 5¾ tons of iron are required.

PURIFICATION OF CRUDE HYDROGEN

The crude hydrogen produced under normal working conditions by the iron contact method has approximately the composition that is given in the following table:

	Per Cent by Volume
Hydrogen	97.5
Carbon dioxide	1.5
Carbon monoxide	.5
Sulphuretted hydrogen	.03
Nitrogen (by difference)	.47
	100.00

In purifying the crude hydrogen it is first scrubbed with water to remove the mechanical contained impurities and reduce the amount of carbon dioxide. The hydrogen is then passed first through boxes containing iron oxide to absorb the sulphuretted hydrogen and then passed on through boxes containing slacked lime to absorb the carbon dioxide. After this purification the purity of the hydrogen is approximately:

Hydrogen	99.0
Carbon dioxide	nil
Carbon monoxide	.5
Sulphuretted hydrogen	trace
Nitrogen (by difference)	.5
	100.0

A plant of the iron contact method consists of three principal items:

(a) A hydrogen shaft or retort furnace containing the iron working substance which is alternately oxidized by the steam delivered from
(b) a boiler, and reduced by the products delivered from
(c) a blue water-gas generator.

Added to these are

(d) purifiers for the blue water-gas, and for the hydrogen
(e) holders for the two gases
(f) compressors for the hydrogen, and
(g) cylinders or reservoirs for the storage of the compressed hydrogen.

SUMMARY

No other method for large commercial productions of hydrogen up to the present time has been developed to replace the iron contact method for purity of the gas and low cost of production.

CATALYTIC WATER-GAS PROCESS

For the production of hydrogen from this process the material employed is steam, blue water-gas and a catalytic agent.

The steam and blue water-gas are passed over the catalytic agent—the steam is decomposed by nature of the catalyzer

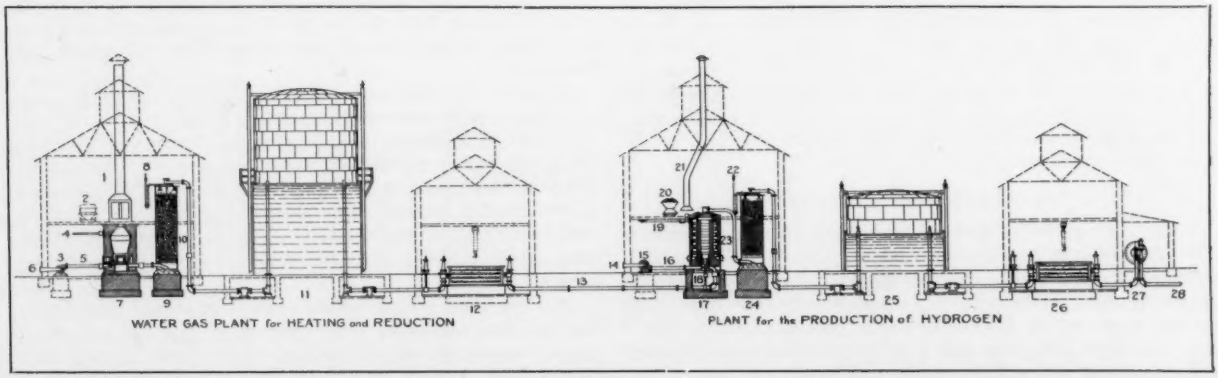


FIG. 7. DIAGRAMMATIC VIEW OF HYDROGEN PLANT JOINED TO WATER-GAS PLANT (MESSERSCHMITT PROCESS)

1. Flue for spent gases; 2, coke car; 3, fan blower; 4, steam; 5, air; 6, air intake; 7, water-gas generator; 8, water; 9, scrubber; 10, water-gas; 11, equalizing gas holder for water-gas; 12, purifier for water-gas; 13, water-gas; 14, air intake; 15, fan blower; 16, air; 17, hydrogen generator; 18, steam; 19, steam; 20, coke and spaethic iron ore car; 21, flue for spent gases; 22, water; 23, hydrogen; 24, scrubber; 25, unpurified hydrogen gas holder; 26, hydrogen purifiers; 27, melter; 28, purified hydrogen to storage tank

which in itself does not undergo any permanent change as when steam is passed over iron in the iron contact process.

The catalyst employed in the process to be discussed has a composition of the following chemicals:

Ferric nitrate	40 parts
Nickel nitrate	8 parts
Chronium nitrate	5 parts

These salts are made into a solution and precipitated with potassium carbonate, filtered and washed and formed in masses to dry. The activity of the catalyst mass is at a temperature between 400 and 500 deg. cent.

The blue water-gas is prepared in the usual manner as previously described.

Into the blue water-gas steam is introduced and the mixture passed over the catalyst with the following reaction:

$$H_2\ CO\ H_2O = 2H_2\ CO_2$$

The carbon monoxide contained in the blue water-gas is oxidized by the steam and is itself decomposed into hydrogen.

MODE OF OPERATION OF THE PROCESS

The blue water-gas combined with the proper amount of steam is passed over the catalytic mixture at a temperature between 400 and 500 deg. cent. After the reaction chamber is heated to the above temperature the oxidation of the carbon monoxide is exothermic and no more heat need be supplied from external sources. The product of the reaction is passed under pressure through water where the greater part of the carbon dioxide is absorbed.

The composition after the introduction of the steam is passed over the catalyst is:

	Per cent by Volume
Hydrogen	65
Carbon dioxide	30
Carbon monoxide	1.2-1.8
Nitrogen	2.5-5.4

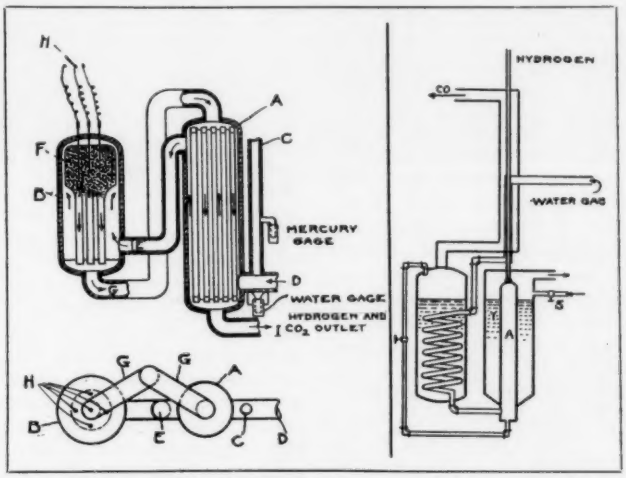


FIG. 8. CATALYTIC WATER-GAS PROCESS HYDROGEN PRODUCER

FIG. 9. HYDROGEN SEPARATOR

In the final purification the carbon dioxide is absorbed by water and passed through hydroxide of sodium or calcium. The carbon monoxide is removed except traces by passing the gas under pressure through ammonical cuprous chloride solution. The result of this final purification of the gas is approximately as follows:

	Per cent by Volume
Hydrogen	97
Nitrogen	2.7
Carbon dioxide	—
Carbon monoxide	.3

In effecting the purification of the hydrogen by the removal of carbon dioxide and carbon monoxide the hydrogen on leaving the generator is compressed at 30 to 200 atmospheres depending on the pressure required for its use, and then passed through the bottom of a tower. In this tower, packed with flints the gas meets a downward flow of water which absorbs the carbon dioxide and slight traces of sulphuretted hydrogen which are present. The gas on leaving this tower is again passed to the bottom of a second tower containing a solution of ammoniacal cuprous chloride which absorbs the carbon monoxide. The cuprous chloride solution is restored to its normal condition by passing it through a small enclosed cylindrical tank in which it gives up its carbon monoxide. To prevent any loss of ammonia evolved from the solution the gas is passed through water.

THE GENERATOR

The generator in Fig. 8 consists of a superheater or regenerator *A* and a catalytic chamber *B*, both entirely insulated with asbestos to prevent heat loss and bound by painted canvas.

Steam is introduced through pipe *C* and mixes with the blue water-gas entering pipe *D*. The mixture of steam and gas passes through the superheater *A* and flows over the refractory tubes as indicated by the arrows and the hot products of the reaction flow through the tubes in the reverse direction.

The mixed heated gases flow through pipe *E* into the catalytic chamber *B* and increasing in temperature, pass through the catalytic mixture *F*, where the reaction takes place with the evolution of heat. The gases then blow back through pipe C as indicated by the arrows into the superheater, parting with their heat to the incoming mixture of blue water-gas and steam and then to hydrogen CO_2 outlet *I* to purifiers.

Placed into the contact mixture are thermo-couples *H* to control its temperature, thereby controlling an increase or reducing the amount of steam in the incoming gas mixture.

A number of patents have been taken out relating to the general chemical reaction of the process just described, among the most important are:

Tessie du Montay—U. S. Patents, 229338, 1880; 229339, 1880; 229340, 1880. Ellis & Eldred—U. S. Patent, 854157, 1907; Pullman & Elworthy-English, U. S. Patent, 22340, 1891; Chem. Fabrik Greisheim Eleckron, U. S. Patent, 2523, 1909; Naber & Muller, German Patent, 237283, 1910.

The process and generator described in this article is based on the patents of the process of the Badische Analin & Soda Fabrik and are:

French Patent, 459918, 1913; English Patents, 27117, 1912; 27963, 1913.

SUMMARY

The advantages of this process appear to be:

1. Moderate cost of installment;
2. Continuous operation;
3. Economical, since the oxidation of the carbon monoxide is exothermic, after the reaction chamber is heated to temperature of 400 to 500 deg. cent., no more heat need be supplied from external sources. The consumption of blue water-gas is approximately 1.1 to 1.3 cubic feet per cubic foot of hydrogen, which is less if compared with consumption of 2.3 to 3.5 cubic feet of blue water-gas per cubic foot of hydrogen by the iron contact method;
4. The sulphur compounds in the blue water-gas are entirely converted into sulphuretted hydrogen and are completely absorbed by the high pressure scrubbing.

The disadvantages are:

1. The intricate operation of the process—great precautions must be taken in the preparation of both catalyzer and the blue water-gas to avoid chlorine bromine, iodine phospho-

rus, boron, arsenic and silicon in some forms, otherwise if these substances are not excluded they "poison" the catalyzer. Always an uncertainty of continuous operation due to catalyzer poisoning;

2. The plant can be operated only by those of highest technical training;

3. The purity of the hydrogen being only 97 per cent and containing 3 per cent of nitrogen is not adaptable for some purposes.

A PHYSICAL LIQUEFACTION WATER-GAS PROCESS—LINDE-FRANK CARO PROCESS

In this process water-gas, consisting almost solely of carbon monoxide, CO, and hydrogen, is cooled and compressed until the carbon monoxide is liquefied, while the hydrogen still remains gaseous and can be drawn off. The apparatus consists essentially of a water-gas plant (Fig. 9) and a plant for the separation of the hydrogen from the carbon monoxide gas.

The water-gas from the producer is first washed and purified, as stated in the production of blue water-gas.

The hydrogen is separated from the rest of the gases by compression and cooling. The boiling point of hydrogen, 253 deg. cent. is much lower than that of the other constituents of the blue water-gas, that of carbon monoxide being 190 deg. cent. and that of nitrogen 195.5 deg. cent. On cooling compressed water-gas to the temperature of liquid air, 191.4 deg. cent. all of the constituents except the hydrogen are liquefied. The hydrogen thus easily separated in the gaseous state is of a high degree of purity.

Before this separation by cooling is attempted the water-gas undergoes preliminary treatment for the extraction of carbon dioxide which, if not removed, would be in a solid state and would therefore block the narrow tubes of the rectifying apparatus. The removal of the carbon dioxide gas is effected for the most part by compressing the water-gas, in contact with cold water, up to a pressure of 20 atmospheres. At high pressure water absorbs carbon dioxide more easily than at atmospheric pressure, hence the quantity of water required for absorption is reduced. The small traces of carbon dioxide, sulphuretted hydrogen still remaining in the water-gas are extracted by passing the latter through tubes containing sodium hydroxide. This dried compressed water-gas then passes through the temperature exchanger of the separator to the coil (Fig. 9) immersed in a bath containing liquid carbon monoxide.

In this coil the carbon monoxide is almost entirely condensed and collects in the bottom of the liquefier *A*, whence it can be discharged by means of a cock into the bath surrounding the coil. The remaining gas passes through the liquefier *A* surrounded by liquid nitrogen evaporating under vacuum. In this way more carbon monoxide is condensed, and the gas issuing at the top is composed of about 97 per cent hydrogen. The remaining carbon monoxide can be removed by passing over soda lime.

This method of compressing water-gas and cooling it by liquid air produces hydrogen 97 per cent pure as will be seen from the following:

	Per Cent by Volume
Hydrogen	97.0
Nitrogen	1.0
Carbon monoxide	2.0

PURIFICATION OF THE HYDROGEN

Where hydrogen of over 99 per cent is required it is necessary to remove the carbon monoxide by passing the gas through heated soda lime, where the carbon is absorbed in accordance to the equation:

$$2NaOH + CO = Na_2CO_3 + H_2$$

Purification may also be effected by passing the gas through heated calcium carbide (over 300 deg. cent.) which removes both the carbon monoxide and nitrogen.

After purification (with soda lime) the analysis of the gas is:

	Per Cent by Volume
Hydrogen	99.2-99.4
Carbon monoxide	nil
Nitrogen	0.8- 0.6

with a specific gravity of 0.77 to 0.79.

As indicated above the hydrogen after purification will average in purity 99.2-99.4. This rectification is costly.

The hydrogen leaves the apparatus under a pressure of 25 atmospheres, which is a considerable saving of power when cylinders have to be filled with gas under pressure.

The residual gases which have been separated by liquefaction consist chiefly of carbon monoxide. They are passed into a small gasholder and used in a gas engine for providing the power required for the plant. With small installations these residual gases have to be supplemented by producer gas, which can be formed to the extent to which it is required in the blue water-gas generator.

The hydrogen plant can be run either continuously or intermittently but it is advisable to shut down the hydrogen separating section every seven days in order that all the worn tubes may be cleaned. A second unit of this section of the plant is kept in reserve for use while the first unit is being cleaned. The plant can quickly be brought into action and its output accommodated to requirements. Plants of this type are constructed in stationary and portable form.

It has already been explained that the hydrogen is obtained by the separation by liquefaction of a gas rich in carbon monoxide. This gas, which is ordinarily used for driving the plant may be utilized as a source of energy for the manufacture of oxygen and nitrogen by rectification of the liquid air which is used for cooling in the separating apparatus. This combination of recovery of hydrogen, oxygen and nitrogen in different proportions makes it possible to apply the liquefaction water-gas process not only in cases in which hydrogen only is needed, but also in some instances for metallurgical purposes in which hydrogen and oxygen are used for high temperature work. The cost of hydrogen from this process depends upon the size of the plant. Estimating the cost of hydrogen from a plant producing 3,500 cubic feet per hour, not taking into consideration depreciation, etc., a unit volume of blue water-gas yields 0.4 volume of hydrogen of 97 per cent purity, or, on the basis of a coke consumption of 35 pounds per 1,000 cubic feet of water-gas, the hydrogen yield is 25,500 cubic feet per ton of coke.

SUMMARY

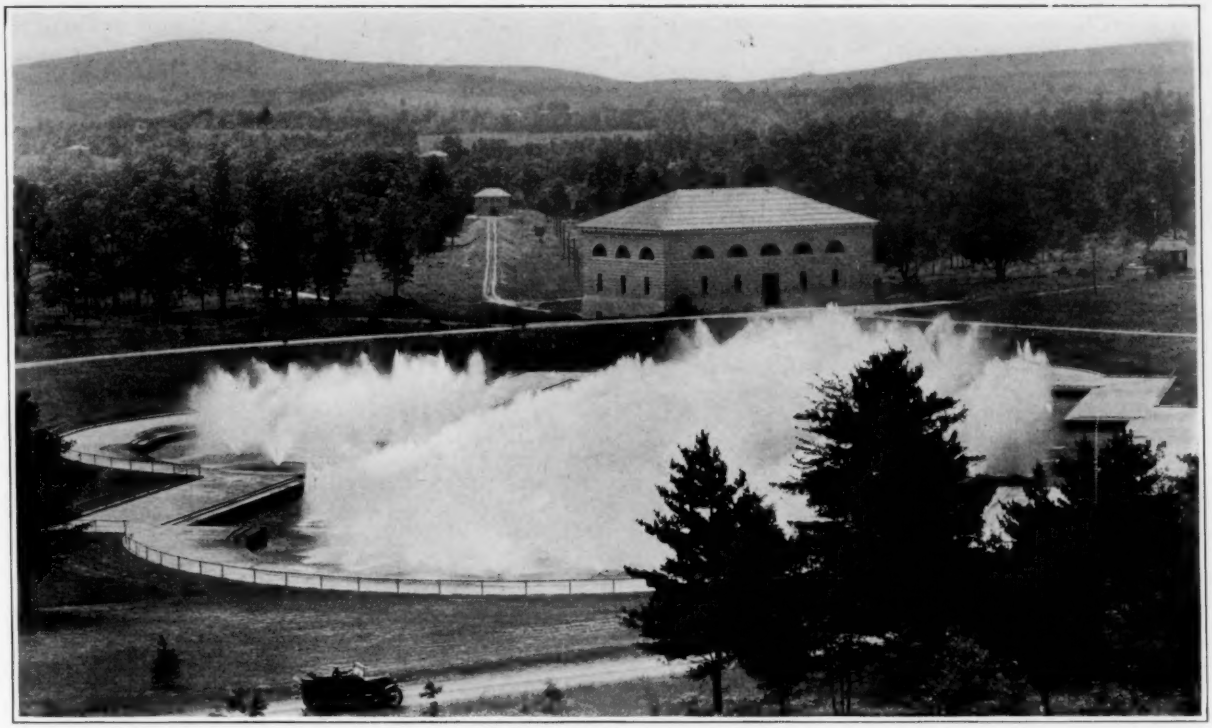
1. A plant for the production of hydrogen by the Linde-Frank-Caro process requires highest technical skill to operate;

2. The plant is very costly and intricate;

3. The purity of the hydrogen being only 97 per cent pure is not adaptable for all industrial uses. Therefore to bring the hydrogen to higher degree of purity requires repurifying which is costly.

DIESEL ENGINE BLOW-LAMP

IN the *Shipbuilding and Shipping Record* for February 10, 1921, there appears a description of an improved blow-lamp for Diesel engines. The simplicity of this heater is one of its principal advantages. The container, filled with parafin is mounted on the cylinder. To start up the engine, a little asbestos fiber is fixed in a suitable position on the cylinder and is soaked with methylated spirit or paraffin and ignited with a match. The paraffin in the container is subjected to pressure and on opening the valve a finely atomized spray plays on the burning asbestos. The resulting flame is said to be sufficiently intense to enable any size of British Kromhout engine to start within 4 minutes.—Abstracted through the *Technical Review.*



THE AERATOR AT KENSICO RESERVOIR

Safeguarding the City's Water Supply

What the City of New York Does to Preserve the Purity of Its Drinking Water

THE City of New York has an ever watchful little band of scientists, who, without any display or striving for publicity perform as important a part as guardians of the public health as do the quarantine officers of the port. So quietly is all the immense volume of work carried on that few people know that there are three laboratories which guard the water at its source, during its path and finally near the ultimate consumer. The laboratories carry on a variety of work which is interchanged when necessary. It is interesting to go over the subject in detail with a qualified expert like Dr. Frank E. Hale, Chief Chemist of the Department of Water Supply, Gas and Electricity, and Director of Laboratories the largest of which, the Mount Prospect Laboratory, is situated in Brooklyn. All of what follows is abstracted from a paper which he read before the Municipal Engineers on May 28, 1919, and which was printed in full in *The Municipal Engineers Journal*. The figures are now somewhat larger than those of 1919 which are given throughout, but the main facts and statistics remain unchanged.

COMPLEXITY OF SUPPLY

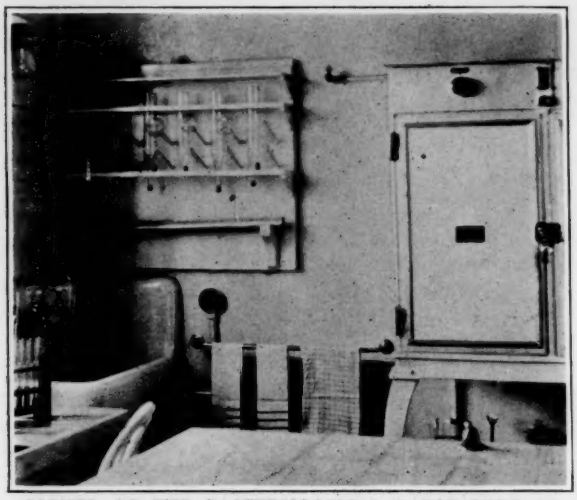
The available supply for New York City is at present about 800 million gallons per day with a consumption of about 600 million gallons daily, and with the development of the Schoharie watershed 250 million gallons daily additional supply will be added, making a grand total of 1,050 million gallons daily. The present available supply is procurable as follows:

Croton watershed, 336 million gallons daily; Bronx and Byram watersheds, 18 million gallons; Esopus watershed, 250 million gallons; Long Island watersheds, including Queens (in reserve), 150 million gallons; Staten Island watershed (in reserve), 12 million gallons; private water companies, 34 million gallons; making a total of 800 million gallons daily.

The supervision by the Department of Water Supply, Gas and Electricity as to the quality of the water supply extends to the private companies of which there are seven in Brooklyn and Queens operating eighteen separate pumping stations. These supplies are entirely from wells. The Long Island Municipal watersheds comprise the Ridgewood system (two infiltration galleries, nineteen well systems and twelve ponds andl reservoirs), Oakland Lake in Queens, and the separate well systems of Brooklyn and Queens (three in Brooklyn and two in Queens). The Staten Island watershed is composed entirely of well systems (five). The Ridgewood system, at present in reserve, derives three-quarters of the water from underground sources. About 35 million gallons daily are available from the Massapequa and Wantagh infiltration galleries. These are really horizontal wells extending for six miles parallel to the south shore of Long Island, intercepting the flow at a depth of fifteen to twenty feet below the surface of the ground and collecting the water through open joints of tile pipe protected by coarse gravel. The area of the Ridgewood system is 168 square miles and must be carefully watched, particularly because of its lack of adequate storage and its nearness to the city, Massapequa pond lying only 27 miles east of the Ridgewood reservoirs. The well systems that are situated within the Boroughs of Brooklyn, Queens and Richmond pump directly to the distribution systems, which is also true of the private companies.

Stringent rules and regulations have been promulgated and are enforced to prevent any contamination of drinking water supplied to any part of New York. These rules require all sewage-disposal systems to be operated and maintained in a manner approved by the Department and require new sewage-disposal systems and alterations of those in existence to be approved by the Department. The rules regulate the disposal of human excreta, house slops, sink, laundry, garage and stable waste, all polluted liquids, dead animals,

manure, garbage, compost, vegetable or any putrescible matter, drainage from stables, pig-sties, poultry, barn-yards, slaughter houses, standing places for horses, cattle, etc., factory waste, washing of cloths or unclean objects, bathing, swimming, etc.



CORNER OF THE BACTERIOLOGICAL LABORATORY AT ASHOKAN WHICH RESEMBLES AN OPERATING ROOM IN NEATNESS

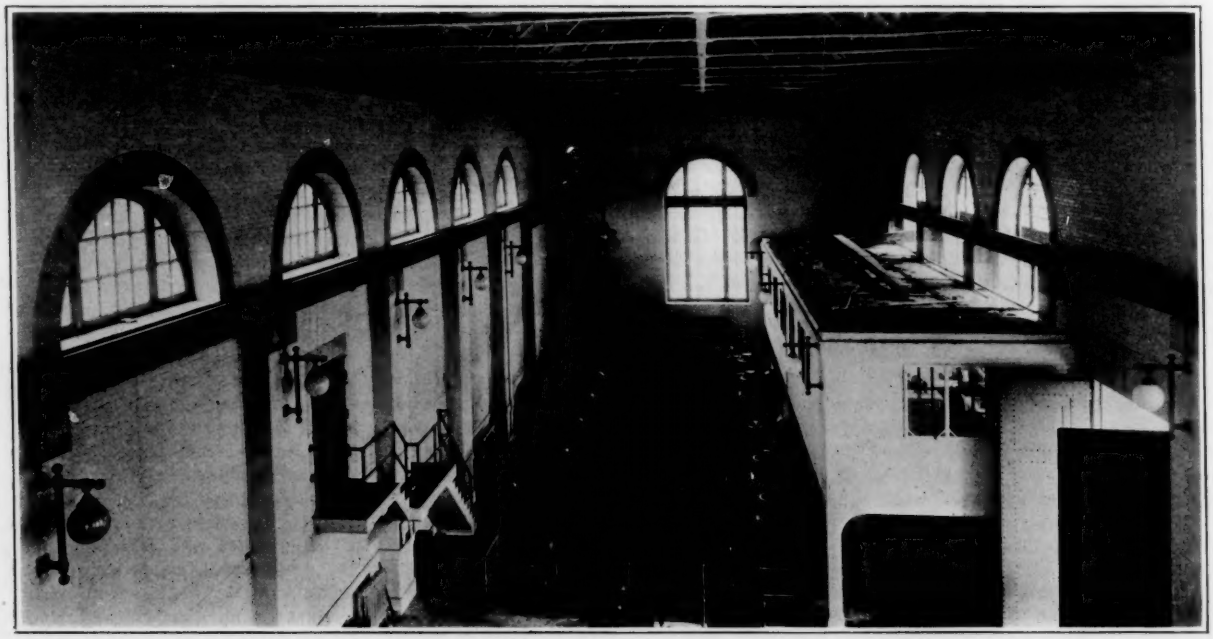
Distances are specified and penalties provided. Most of the rules are stated negatively indicating what may not be done.

SANITARY FORCES

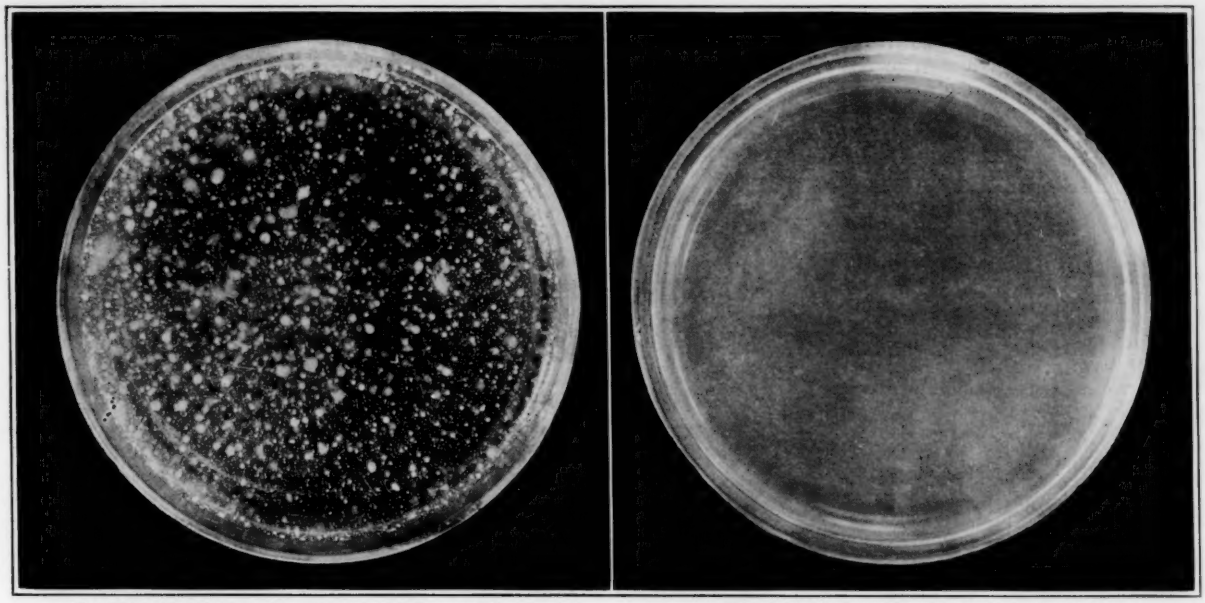
The Brooklyn, Queens and Richmond watersheds are under the control of the respective borough engineers. The Croton and Catskill distribution system likewise are under borough control. The Croton, Bronx and Esopus watersheds are under jurisdiction of a division engineer who has an assistant engineer over the Croton watershed and an assistant engineer over the Esopus watershed. Uniformed inspectors look after the watersheds of surface supplies and tramp the streams and adjoining territory. The Croton watershed is divided into 24 sanitary inspectional districts, with an employee for each district who is held responsible for the sanitary conditions within his district. Each inspector is required to follow daily the prescribed route, averaging about eleven miles, and to report in writing his investigations. Each route in a district is covered periodically, usually once a week. Every case of typhoid is investigated, waste disposal looked after, disinfectants furnished and full information recorded. Sewage disposal, both public and private, is carefully planned, supervised and in some cases operated, and chlorination plants operated or supervised. The Bronx and Byram watershed has five inspectional districts, and contains sewage-disposal and chlorination plants. The Esopus watershed similarly is looked after by an inspectional force covering seven districts, and a chlorinating plant is operated. The Brooklyn watershed, when in operation, is similarly under daily patrol, filtration plants and chlorination plants are operated, and pan system and cesspools cared for by scavengers. Although in reserve, a certain amount of inspection is at present maintained.

LABORATORIES

At present there are three laboratories. Mt. Prospect, the main laboratory is situated in Brooklyn. Here are analyzed completely all samples of water from the distribution systems of the city, and from Long Island, Queens and Richmond watersheds. In addition, during the war, all chemical analyses of water from the Croton, Bronx and Esopus watersheds were handled at the main laboratory. Problems of research, budgetary matters, supplies, reports, etc., are centralized here. At the Mt. Kisco Laboratory, situated at Mt. Kisco, N. Y., are handled complete sewage analyses, including chemical work, of samples from disposal plants on the Croton and Bronx watersheds and all bacteriological samples from these two watersheds. At present the physical and microscopical analyses of samples from the Croton and Bronx watersheds are divided, half and half, between the Mt. Kisco and Mt. Prospect laboratories. The Catskill laboratory is situated at Ashokan reservoir and handles the bacteriological and physical analyses of samples from the Esopus watershed. The chemical and microscopical work is performed at the Mt. Prospect laboratory with the exception of certain special chemical tests in connection with the operation of the Phoenicia chlorination plant. This laboratory is new and beautifully equipped throughout with electrical apparatus. The current is derived



CATSKILL LABORATORY IN A MEZZANINE GALLERY IN THE LOWER GATE HOUSE AT ASHOKAN



PHOTOMICROGRAPH OF WATER FROM A POLLUTED STREAM

2,000 Bacteria per cubic centimeter incubated at blood temperature, 37 deg. cent.

SAME AFTER TESTING WITH LIQUID CHLORINE

Seventeen pounds of chlorine are used to each million gallons of water

from water power. Equipment is also at hand for sewage analyses in case such should become necessary for this watershed.

CHARACTER OF ANALYSES

The analysis of the water samples is very complete and may be grouped as follows:

1. *Physical.*—The physical examination includes turbidity, color and odor. This examination is related to the æsthetic senses, qualities most readily affecting the consumer.

2. *Chemical.*—The chemical examination includes determination of nitrogen in all its forms (free ammonia, albuminoid ammonia, nitrite and nitrate), chlorine, hardness, alkalinity, iron, total solids, loss on ignition and fixed solids. On certain samples, tests are also included for free carbonic acid, free chlorine, total lime, heavy metals, silica and sulphates. The chemical analysis is particularly useful in judging of the history of any particular water and its suitability for boilers or other industrial use. Many of the above determinations are influenced by the number of people dwelling upon the watershed, as well as by the amount of contamination that may reach the water. In well waters the amount of nitrate indicates the degree of oxidation of organic matter, that is, the amount of contamination and purification the water has undergone. Many samples of leaks are sent to the laboratory for identification. These are taken from cellars, excavations for construction work, underground conduits, subways, etc., and examined to ascertain whether their source is city water, sewage, or underground water. Apparently the pressure of the Catskill water has increased the number of leaks, since there were 407 such samples during 1918 compared with 280 in 1917 and 114 in 1916. Both the chemical and microscopical analyses are invaluable in this connection.

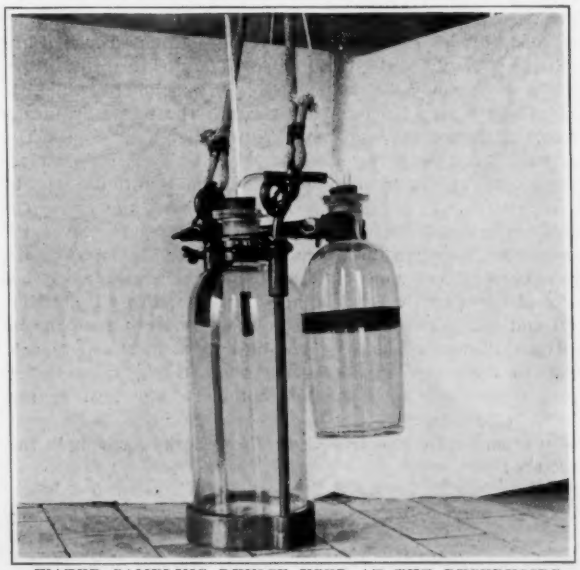
Again the chemical analyses have assisted in preventing the stealing of city water by barges supplying boats in the harbor and by industrial concerns, and in distinguishing between city water and private supplies when the boundary services were uncertain.

3. *Bacterial.*—The bacteriological examination includes the total bacteria growing on agar at blood temperature (37 deg. cent.) and in special cases, particularly well waters, the total bacteria growing on jelly at ordinary temperature (20 deg. cent.). Liquefiers in a well water indicate surface drainage to the ground water. Specific search is made for the various species belonging to the intestinal group of bacteria usually termed "*B. coli*," including twenty or more forms which may be grouped under the species *B. communior*, *B. communis*, *B. latis-acrogenes*, and *B. acidi-lactici*. Specific search is also made for *B. typhi*, *B. para-typhi*, *B. sporogenes*, *B. welchii*, and it is hoped eventually that *B. dysenteriae* may be included.

4. *Microscopical.*—The microscopic work includes the identification and estimation of the quantity of the various thousands of microscopic plant growths which may be present in the water supply. These are important in connection with taste and odor and will be mentioned below in more detail.

MICROSCOPIC ORGANISMS

Complaints are received at periods of disagreeable taste and odor in the water of turbidity, scum, oil, etc. Many of these



WATER SAMPLING DEVICE USED AT THE RESERVOIRS

The water comes through the small bottle into the large one and the residual water in small bottle gives sample from the desired depth

are investigated by the laboratory division as well as by the borough engineers. Frequently the trouble is due to "dead ends" and is readily remedied by flushing through hydrants in the vicinity. But more often the trouble is caused by some microscopic organism. All reservoirs and sources of supply are regularly examined and trouble is usually foreseen and complaints prevented. Certain reservoirs may be by-passed.

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CLEANING THE SCREENS AT THE KENSICO RESERVOIR

These screens take out larger particles, also many fish

Draft may be changed from one basin to another or from the surface to a depth. Aeration has been used for a few years not only, if possible, to remove odor, but to actually break up and disintegrate certain fragile forms. Thus *uroglena* has been completely destroyed and *asterionella* disintegrated. Specific growths may be killed by copper sulphate which is dragged in burlap bags rapidly through the water by means of boats. Thousands of pounds are used annually by the Department for this purpose. Each organism has its own required dose ranging from one part in one million to one part in twenty million by weight of copper sulphate to water. On large reservoirs local sections may be treated and frequently the dose is figured on the upper ten feet only. In fact, certain types, *cyanophyceae*, are most abundant near the surface, being kept afloat by the oxygen gas which they give off. During 1920 and 1921 successful control of microscopic organisms in the Catskill water has been obtained by adding copper sulphate to the water in the aqueduct shortly before entering Kensico Reservoir by means of automatic dry feed at the Pleasantville plant.

The organisms which trouble the New York City supply the most are:

Diatoms

Asterionella, *Tabellaria* } produce geranium to grassy and fishy odor.

Cyanophyceae

Anabaena, *Aphanizomenon* } produce grassy to pig-pen odor.

Protozoa

Uroglena produces fishy odor.
Synura produces cucumber and bitter taste.
Dinobryon produces oily and fishy taste.

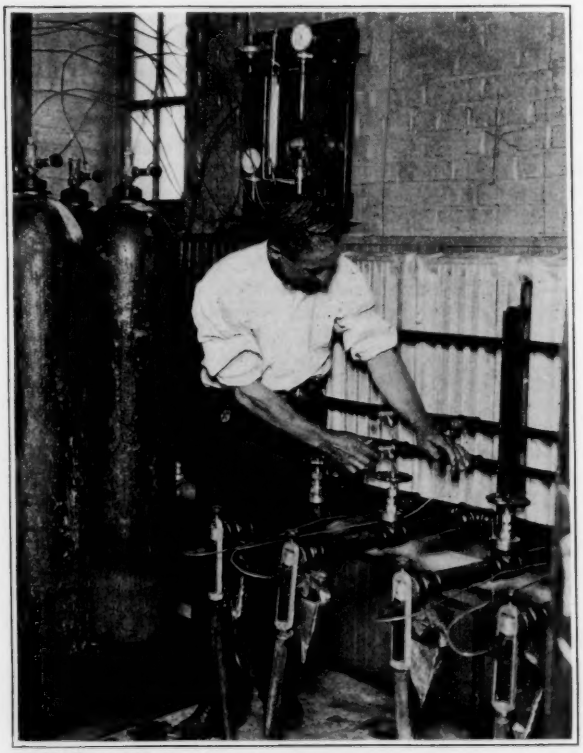
Schizomycetes (*Crenothrix*) clogs well systems.

All of the above, except *crenothrix* have troubled the supply during the last two years.

STORAGE

The first and greatest safeguard which the city supply possesses is the extent of storage on its watersheds. This is not true of the Long Island surface watershed. The Croton watershed contains twelve reservoirs and six lakes, with a total storage capacity of 104 billion gallons, equivalent to one and one-half years' storage at the present rate of draft. Croton Lake itself is twenty miles long, including the upper portion, termed Muscoot Reservoir, and possesses nearly one-third of the total storage. Since the introduction of the Catskill supply and consequent smaller draft upon the Croton supply, plans have been formulated in order to utilize the storage facilities in the best manner possible. Each reservoir is kept near a predetermined level such that it will have sufficient storage capacity to permit of at least two weeks' sedimentation after all but the very severest rainfall.

Ashokan Reservoir has an available capacity of 128 billion gallons equivalent to 256 days (two-thirds of a year) at a draft of 500 million gallons daily. When the Esopus River pours



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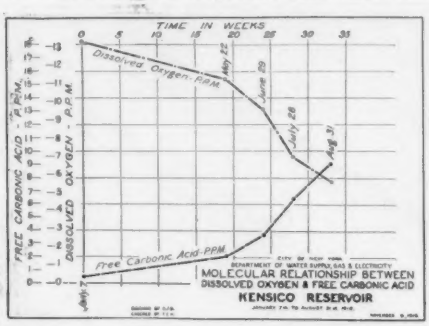
USING LIQUID CHLORINE TO STERILIZE NEW YORK'S WATER SUPPLY

its muddy water during heavy storms into the head of Ashokan Reservoir a sharp line of demarcation forms at the upper end of the reservoir.

THERMOCLINE STUDIES

Many changes take place in stored water at different depths and extensive studies have been made at both Croton Lake and Kensico Reservoir and a few at Ashokan Reservoir. During the summer the surface-water becomes warmer and

through the action of the wind, rain and heat, disturbances take place to a moderate depth, usually from fifteen to thirty feet below the surface. This point is termed the thermocline. Below this point the water is stagnant and decreases in temperature, sharply at first, then more gradually, to the bottom. Above the thermocline the water becomes warm and high in microscopic organisms; below, it is clear, cold and lower in microscopic organisms. The dissolved oxygen becomes exhausted at the bottom and frequently just below the thermocline. As the oxygen decreases, carbonic acid increases. Knowledge of the above has caused the Department during recent years to draw as much as possible from deep water in the reservoirs, thus obtaining water of better quality. In the fall colder temperatures cause the water to overturn so that it becomes of uniform temperature and quality from top to bottom, and this continues throughout the winter.



AERATION

In connection with the headworks of the Catskill aqueduct at both Ashokan and Kensico Reservoirs, aerators were built capable of handling all the water carried by the aqueduct. These are great fountain basins, approximately 500 feet long by 250 feet wide, each containing 1,600 nozzles through which the water is jetted and sprayed as high as thirty feet into the air. These aerators permit water to be drawn from any depth in a reservoir, increasing the oxygen when low, decreasing the carbonic acid (a corrosive element) and removing musty tastes and odors or undesirable gases like hydrogen sulphide. These aerators have actually helped to break up and lessen certain microscopic organisms.

FORESTATION

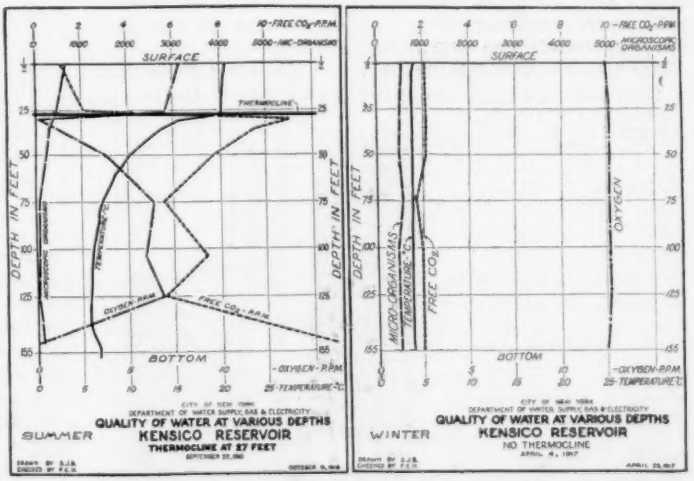
Forests equalize run-off, increase humidity and thus decrease the rate of evaporation. Coniferous trees transpire less moisture than grass, thereby leaving more water in the ground to appear as run-off. When planted between reservoirs and highways they provide a dust screen which prevents the entrance of much road detritus into the reservoirs. When planted thickly they render access to the lake shore difficult. Trees help to prevent the scouring of banks by heavy rainfall and the necessarily turbid water resulting. In addition there is of course the beautifying of the general landscape, particularly when evergreens are present. New York City controls over 15,000 acres on the Ashokan watershed. Upon less than half of this exists a native forest of second growth hemlock, white pine, oak and maple. Chestnut trees have been almost entirely exterminated by the chestnut-bark blight which suddenly sprang up a few years ago. The Board of Water Supply expended considerable effort in reforestation, growing from seed several hundred thousand trees a year. Over a million and a half evergreen trees, two-thirds of which were species of pine, have been planted, particularly on the shores of the reservoir. Likewise at Kensico Reservoir the Board of Water Supply planted over 800 acres with white, red and Scotch pine and Norway spruce. Beginning in 1912 forestation was started on the Croton watershed, particularly near villages, reservoirs and adjacent to the public roads. Three-year-old and four-year-old transplants have been used of white, red, and Scotch pine and spruce obtained from the State Conservation Commission. This work will probably require considerable attention in the future, particularly because of the possible ravages of insects and parasite fungi and of the destruction by fire.

COAGULATION PLANT

In case Ashokan Reservoir should become turbid through wind and wave action on deposited silt during times of low water, an alum coagulating plant was installed on the aqueduct at Pleasantville, about thirty minutes flow above the Catskill influent to Kensico Reservoir. It was designed to add alum to the water which would be flocked by the time it reached Kensico, entangling the turbidity, which would then settle in Kensico Reservoir. The plant has been tested and its effect on the water studied, but otherwise there has been no occasion to use it for this purpose.

SEWAGE DISPOSAL

Extensive means are taken to prevent sewage from entering the water and adequate purification insisted upon where this is impossible. The Croton watershed has numerous sewage plants installed, of all types, depending upon the existing local conditions. Hundreds of houses and hotels have been looked after. Pan closets, chemical closets, tight cesspools, leaching cesspools, septic tanks, open trenches, subsurface irrigation tile drains, trickling filters, contact beds, sedimentation tanks, Imhoff tanks, sand filters, chlorination, etc., are all practiced. About the only methods not used are the chemical precipitation, activated sludge, yeast process, sulphite process, and electrolytic-lime process, and most of these are too new or untried. Several of the larger plants are under strict analytical control at every step of the process and in several instances the effluents are purer than the streams into which they flow.



CHLORINATION

All surface water before delivery to the consumer is chlorinated, sometimes more than once. In the Borough of Richmond, the well water of the West New Brighton pumping station was provided with facilities for chlorination because of possible contamination of the suction main while crossing polluted brook water. This station is now in reserve. In the Borough of Queens, the water of Oakland Lake after filtration was chlorinated. This supply is in reserve. On the Long Island watershed all water east of Milburn was chlorinated at the Milburn pumping station; also the water of the conduit at

Smith's Pond pumping station. In addition, the water of Watt's Pond, with which the water of Valley Stream Pond was usually mixed, was separately chlorinated. These supplies are all now in reserve. On the Croton watershed, Tonetta Brook at Brewster, Katonah Brook at Katonah and the Kisco River at Mt. Kisco are chlorinated. Lake Gleneida, on the shores of which Carmel is situated, is chlorinated as it flows into West Branch Reservoir. The entire Croton supply is treated with liquid chlorine at Dunwoodie, a point at which the old and new Croton aqueducts closely parallel one another. This plant was originally operated in 1912 with bleach and in 1916 the treatment was changed to liquid chlorine. There are nine units, each regulating gas from ten tanks of liquid chlorine. The latter stand on platform scales and the loss in weight of chlorine is taken at intervals to check the delivery of the apparatus. The gas enters the water at a depth through a battery of 45 diffusers. The cost of such treatment in normal times is about 25 cents per million gallons, exclusive of interest, depreciation and repair. The Esopus River on the Catskill watershed is chlorinated below Phoenicia with bleach. The plant is temporary and will be continued so long as unpurified sewage enters the stream, as is the case at Pine Hill and Chichester. The entire Catskill supply is again chlorinated in the aqueduct just after leaving Kensico Reservoir and following aeration. This plant is similar to the Dunwoodie plant except that the gas is first forced into solution in water in pipes through the use of injectors, and the solution flows through hose into the water of the aqueduct. Thorough admixture is brought about by passage through a Venturi section built into the aqueduct at this point. The water leaving Kensico Reservoir via the 48-inch pipe line at the dam is also chlorinated by liquid chlorine.

FILTRATION

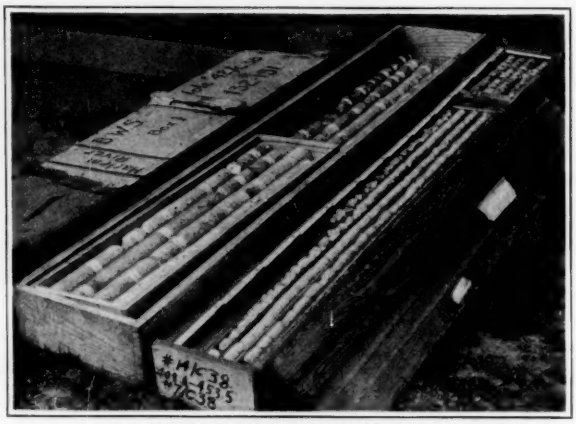
In the Borough of Queens the water of Oakland Lake is passed through a slow-sand filter, operated at a five-million-gallons-per-acre-per-day rate, bacterial efficiency being perfected by chlorination with liquid chlorine.

Our filters were originally built to treat polluted portions of the Brooklyn supply, two of the slow-sand-type—the Hempstead and the Forest Stream filter plants—and two of the rapid or mechanical type employing alum—Baiseley's and Springfield filter plants. The two latter are no longer used for bacterial purification of surface waters. In fact, the Hempstead filter plant is the only one at present available for the original use.

AERATING WATER CHARGED WITH IRON BY FLOWING IT DOWN ZIGZAG TROUGHS

IRON REMOVED

The two mechanical plants have been used during recent years to remove iron from the well water pumped at the Jamaica and Springfield pumping stations, respectively. Alum is not employed, merely sedimentation and rapid filtration. During the last period that they were in operation, the early part of 1917, the efficiency of the former plant was 96 per cent, reducing 10.20 to 0.36 parts per million iron, and of the latter plant 99 per cent, removing 11.00 to 0.13 parts per million iron. In addition to the city plants the efficiency of iron removal is watched at the two plants of the Queens County Water Company at Valley Stream and at Rockaway Park, and also of the plant of the Broad Channel Corporation. The former plant is a slow-sand filter, and the two latter are of the mechanical type. During 1918 the Valley Stream plant removed 95 per cent of the iron (2.35 to 0.11 parts per million), the Rockaway Park plant 98 per cent (24.60 to 0.47 parts per million iron) and the Broad Channel plant 96 per cent (10.80 to 0.43 parts per million iron). It is essential for iron removal to adequately aerate and splash to remove carbonic acid. Ripening of the sand by films of iron oxide is essential, for perfect results, to complete the oxidation of the iron since the iron in solution is in ferrous condition and must become ferric to render it insoluble.



A COLLECTION OF CORE-SECTIONS

There are 44,731 linear feet of cores preserved for reference in the Municipal Building

CHEMICAL MUTATION

INTEREST in the alchemy of the Middle Ages seems to have been revived by the claims of recent inventors as well as by modern theories based upon new theories of radioactivity and observations that helium is an element which in time results from the breaking down of the other element, radium. The American Chemical Society News Service reporting a recent address by Dr. Ira Remsen points out that Sir William Ramsey was always interested in the possibility of changing one element into another and believed that upon one occasion he obtained a trace of lithium from copper although the result was never confirmed. More and more scientists are coming to the belief that the various elements as now known may after all be composed of various combinations of very much fewer kinds of matter and the dream of the alchemist, according to Dr. Remsen, may some day be realized. He says:

"It took centuries of effort to convince chemists that the claims of alchemists were without foundation. But the chemical profession went to the other extreme and held that the change of one element into another is impossible. The whole question is an open one, and this has come about through the work of Sir William Ramsey on radium. It is probable that many workers will experiment in this field, and it is fair to predict that some time someone will succeed. Whether it will ever be possible to transform silver or any other metals into gold, no one can say. In any case the subject is well worth investigating, and it is obvious that we shall never know the outcome without a great deal of careful research."

Molten Tungsten*

New Developments in the Manufacture of Tungsten and Its Compounds

By Hugo Lohmann

For the past few years, owing to the development of electric lighting and to the progress made in the manufacture of various alloy steels, whose importance and usefulness both from the industrial and military standpoint are of the highest significance, the various large electrical and metallurgical companies both in America and in Europe have been striving to solve the problem, which is beset with so many technical difficulties, of fusing tungsten and the other metals whose melting points are very high so as to be able to work with them in large quantities as one does with iron or steel. The problem has been one of plant scale operation only, as it is possible to melt the metal in small amounts in the laboratory. In making the tungsten filament for incandescent electric lamps, the metal is sintered. In manufacturing the powdered tungsten for use in alloying steel, chemical processes of precipitating the metal from the solutions of its salts are used. The properties, which this metal bestows on the steels that are alloyed with it are well known. We naturally are very much interested in learning what properties tools and machine parts made entirely from this metal would possess. We have been unable to do this up to the present time, because it has been impossible to melt the metal on a plant scale operation. The author of this article professes to have perfected a method by which this can be accomplished. He also suggests a method of producing a substance whose hardness is greater than that of the diamond.—EDITOR.

AFTER it had been ascertained that the diamond was merely a form of crystallized carbon, which could be obtained by the combined action of high temperature and high pressure, the next step was to build furnaces in which these two conditions could be realized. Due to the labors of the famous French chemist, Moissan, an electric furnace was developed in which Moissan succeeded in synthesizing the diamond. Before Moissan's time the highest temperature procurable in the electric furnace was from 1,500 to 1,600 deg. cent. only. The furnace that Moissan used developed a temperature of 2,000 deg. cent., due to the use of a blast of oxygen. The first industrial application of the furnace was in the melting of platinum, which was effected in a limestone crucible at a temperature of 1,775 deg. cent.

The furnace designed by Moissan gave a highest theoretically attainable temperature of 3,500 deg. cent. The inventor did not limit himself to experiments with the diamond only, but investigated the melting points of a whole series of metals such as chromium, titanium, molybdenum, vanadium, boron, zirconium, tungsten and uranium. Moissan was the first to melt tungsten and deserves a great deal of credit for this achievement, but his experiments were conducted in very small crucibles which were only half a millimeter in diameter. The quantities of metal obtained thus are of course of no industrial importance whatever. However, enough of the molten metal was procured so that its properties could be studied both from the physical and chemical standpoint. Moissan also made tungstic carbide, whose formula is CW_2, in his furnace and investigated its properties. He noted that the pure tungsten metal obtained in this way could be polished, forged, cementated easily and possessed no action on the magnetic needle. (For further information on Moissan's work, see *The Electric Furnace* by Henri Moissan and *Comptes Rendues*, Vol. CVI, p. 1,225.)

Moissan suggested that it was possible to produce crude tungsten in large quantities in the electric furnace and that the crude metal could then be purified by melting it with an excess of tungstic acid, but he did not press the matter any further. He was eminently the pathfinder. The chemical and electrical industries, however, soon came to appreciate the advantages that these high melting-point metals possessed, especially the metal tungsten, which melts at 3,000 deg. cent.

To many it appeared that the only way in which such a high temperature could be obtained was with the aid of the electric furnace. There is however another means of obtaining high temperatures, viz., by the use of the aluminothermic method, which consists in reducing metals from their oxides by means of aluminum. The temperature that is procured in this way approaches that of the electric arc. In the years 1911, 1912 and 1913 the author succeeded in obtaining temperatures exceeding that of the electric arc by the aid of an especially constructed furnace. At the same time he was able to eliminate the principal disadvantage of the arc type of furnace, viz., the smallness of the source of heat and the space within which it is able to prevail. In this manner a furnace was constructed in which such large quantities of heat were evolved that it became possible to melt tungsten in large amounts, even in the form of the carbide, and, accordingly, it was possible to use the metal in making various articles of industrial importance. The author was able to liquefy 5 kilograms or about 12 pounds of amorphous tungsten in his furnace within 15 minutes and to obtain therefrom a thoroughly fused carbide.

Besides the possibility of producing any desirable quantity of molten metal or carbide and of using the same for various industrial purposes which was afforded by this apparatus, the furnace, in addition thereto, possesses certain important technical and economic advantages. The consumption of the current in the furnace is almost equal to the theoretical amount of energy required by the process. After the carbide of tungsten was successfully prepared in this apparatus, the carbides of all the other high melting-point metals such titanium, vanadium, zirconium, silicon, boron, uranium, etc., were also produced in commercial quantities.

The next step, after the commercial manufacture of tungstic carbide had become a *fait accompli*, was to produce the metal tungsten itself in the pure state free from carbon. The author succeeded in solving this problem by combining the aluminothermic reaction with the electric arc furnace. (The author hesitates to disclose the exact details of this apparatus, but promises a more comprehensive article in the near future.) While the idea itself was very simple, the practical application proved to be fraught with many technical difficulties. The aluminothermic reaction takes place with great volence, and the heat, that is generated, is evolved in a very short space of time, which makes it an extremely difficult matter to control and to guide the same into the proper channels, so as to make it accomplish what is required of it. It took several years of patient experimentation before a method was devised whereby

*Translated from *Elektrochemisches Zeitung*, 26, 29-33.

it was possible to mitigate the vigor of the reaction so that the heat evolved therein could be used in conjunction with that of the arc furnace to produce very high temperatures at which pure metallic tungsten, etc., could be manufactured. Inasmuch as the reduction of the metal from its oxide was affected by means of the aluminum, it was no longer necessary to use carbonaceous matter for this purpose and a carbon-free product was obtained. This is a point of great technical significance as the presence of carbon in the metal destroys some of its most valuable properties.

The extremely high temperature in the aluminothermic arc furnace necessitates the use of graphite in the construction of the crucibles, as this is the only substance that is refractory enough to withstand the action of the tremendous heat. The highly reducing effect of the liquid metal on the sides of the crucible is counteracted by suitable means (probably by the formation of an oxidizing atmosphere within the reaction chamber), so that the final product does not contact with any carbon.

THE PROPERTIES AND USES OF TUNGSTIC CARBIDE

Tungstic carbide possesses a hardness of 9.8 on the Moss scale. Hence, it is but little removed from the diamond, which is 10. It can replace the diamond entirely for all industrial purposes where the variety of this precious stone, known as bort, is used. It has been possible to make articles from tungstic carbide which are strong, compact and elastic enough so that they do not crumble away under use. This compound has been used to make the dies for wire drawing machines. Various cutting tools, facings for stone cutting machines and boring apparatus for oil and water wells and other purposes have been made from tungstic carbide. The results that have been obtained have been so excellent that there is no question at all that the carbide can supplant the industrial diamond in all its applications and that the manufacture of synthetic bort is altogether an unnecessary industry. The one great advantage of this new substance is that it can be made into any form that may be desired and that the cutting surface may be shaped so as to give the best results, while in the case of the bort we are limited to the crystalline form in which it is found in nature. A commercial advantage lies in the fact that the industry is not subject to the production of the diamond mines and to the price variations in the diamond market.

THE PROPERTIES AND USES OF THE METAL TUNGSTEN

The possibility of melting tungsten, of being able to pour it into molds and make with it all sorts of castings, of being able to forge it, roll it and cementate it has opened up the entire chemical, metallurgical and electrical field to this metal. It has been found that when the electric light filaments are made from the molten tungsten by drawing out wires of fine diameter, the candlepower of the lights is greater and the consumption of current per candlepower is less than in the ordinary sintered filament. Furthermore, the great hardness, high mechanical strength, high elasticity, great toughness and durability and extreme resistivity to high temperatures of the cast or forged metal render it very useful for various industrial and military purposes. We all know the remarkable properties of tungsten steel and the use of the pure tungsten metal, free from all contamination by carbon, for the same purposes gives results that are still more remarkable The author has professed to have made all sorts of high speed cutting and lathe tools with the metal and to have used the same with most extraordinary success. It can be readily understood that the cutting edge of the tool would stand up very well under the heat produced in the course of the cutting operation in the lathe, because of the very high melting-point of the metal. It was also found that the metal could be tempered very successfully. In fine, it is the metal par excellence for all work where great hardness is required and where the tool or machine part is subjected to great wear and high temperatures produced by frictional resistance.

The military importance of the metal has been mentioned and has been recognized as of the highest significance. The great guns that are used in naval armaments, in coast defense and in siege operations are all lined with tungsten steel. The reason for this is that the shell in its passage through the bore of the gun, after it has been fired, generates a great amount of heat due to the frictional resistance between the shell and the bore. Steel, alloyed with tungsten, withstands this heat best of all the alloys, but even then, after a certain number of shots have been fired, the gun must be relined for the high temperature has affected the surface of the bore so that it is no longer true and the shell, on leaving the gun, is no longer directed so as to reach its mark, as indicated by the position in which the gun has been pointed by the marksman. The expense of such relining is very great and the outcome of a misdirected shot in the heat of battle, because of a defective gun, may be very vital to its final outcome.

From what has been said above it is evident that the metal tungsten possesses properties which fit it for use in lining guns better than any other known substance. If it can really be melted in large quantities and worked in the same manner as the alloy steel is worked then there is no reason why the linings cannot be made from it.

THE PRODUCTION PROPERTIES AND USES OF URANIUM

The author has succeeded in preparing the metal uranium in the same way as tungsten. Uranium melts at 3,500 deg. cent. and possesses the highest atomic weight of all the metals, viz., 238.5. In X-ray work it has been known for a long time that the effectiveness of the X-ray tube varies directly as the atomic weight of the metal, from which the mirror is made, which is placed at the focal point of the kathode rays. Platinum has been used for this purpose. It is evident that the metal uranium would be better suited for this purpose because of its high atomic weight. The author was able to verify this fact by actually making X-ray tubes with uranium mirrors.

A further use of uranium is found in electrical technology in its substitution for platinum in making contact points for the spark plugs of gas engines, in making lamina and instead of platinum in the small piece of wire that is used to make contact through the glass part that holds the filament in the electric light.

The author has also been able to produce the difficultly fusible metal titanium in large enough quantities to render it possible to use the same for all industrial purposes.

A SUBSTANCE HARDER THAN THE DIAMOND

As is well known, the diamond is the hardest substance known. The diamond is crystallized carbon and the only substances that approach it in hardness are the carbides of the high melting-point metals such as tungstic carbide, silicon carbide, etc. In each it is noticed that the hardness is obtained by the addition of carbon. The question arises, is it possible to make a substance that is harder than the diamond?

It is known that every metal when it does not contain any carbon no matter how hard it may be is malleable at a certain temperature and consequently can be forged or rolled. In the forging or rolling process the position of the molecule is changed so that the structure of the metal becomes more compact and the so-called fibrous structure is obtained. This results in the production of a harder metal.

If we have, to start with, a substance that contains no free carbon and that possesses a hardness very close to that of the diamond then naturally, when this substance is subjected to rolling or forging, its hardness must be increased. We know that tungstic carbide has a hardness of 9.8 and does not contain any free carbon. The addition of carbon to it will increase its hardness as will rolling or forging it and the experiments that have been instituted in this direction will undoubtedly yield a substance whose hardness will surpass that of the diamond.

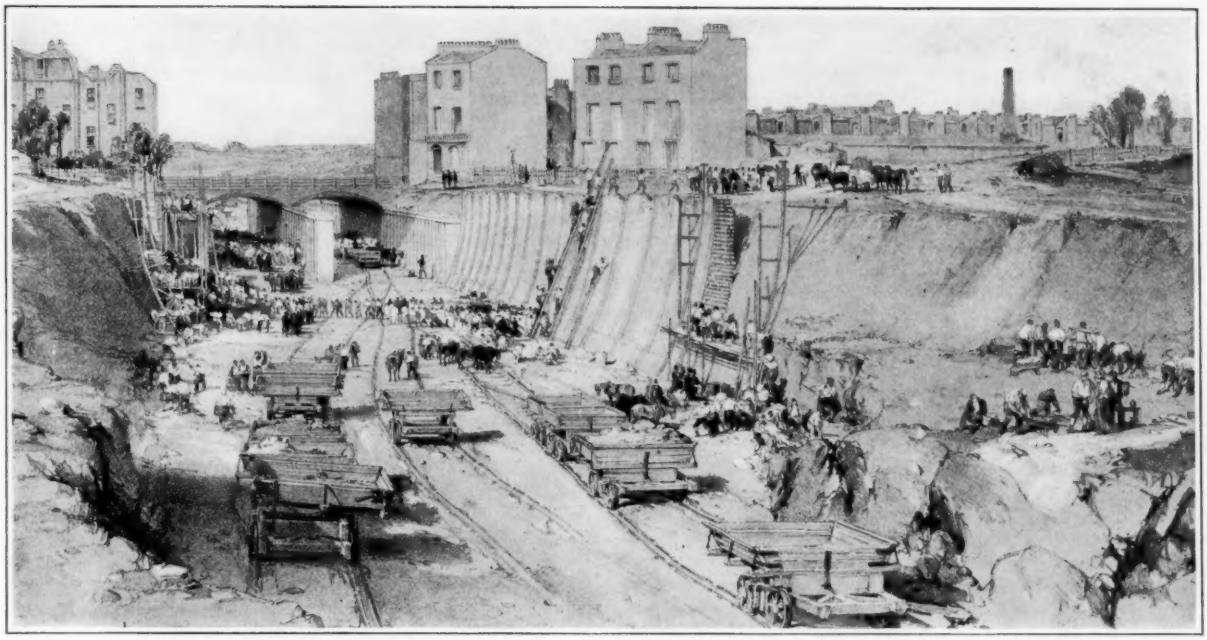


FIG. 1. BUILDING RETAINING WALLS, PARK STREET, CAMDEN TOWN, SEPTEMBER 17, 1836

Early Railroad Engineering

The London and Birmingham Railway—A Story of Its Difficulties, Failures and Success

By Herbert T. Walker

Illustrated from contemporary prints

LORD MACAULAY once said that "of all inventions, the alphabet and the printing press alone excepted, those inventions which abridge distance have done most for the civilization of our species."

At the present day, when railways are so far a necessity of our lives that without them existence would soon become impossible, it would be idle to discuss the truth of the proposition above quoted; but to the reflective mind it is profitable to look back and note the steps by which our gigantic system of transportation has been developed since the days of the Brunels and the Stephensons and the few far-seeing business men who supported them.

The London and Birmingham Railway was a representative pioneer railroad, for it was the first main line to enter London. It was antedated by other short lines within the metropolitan area, but in national and historical importance they were not in the same class as the railroad forming the subject of the present article, and it is thought that some notes, illustrated from a few old and rare lithographs by Bourne, will be of interest and value.

The London and Birmingham Railway was closely associated with the Liverpool and Manchester Railway which is known as "the great experimental railway of the world"; this for the reason that in its construction and working, principles were evolved and practice laid down which have formed railway engineering precedents from that day to this. Furthermore, both lines were designed and constructed by George and Robert Stephenson, whose names will always stand at the head of the list of our greatest engineers. And, lastly, the London and Birmingham and the Liverpool and Manchester lines now form a part of the great London and Northwestern Railway, which is one of the most highly organized and efficiently managed systems of transportation in the world. It has been called the "Pennsylvania Railroad" of Great Britain.

It is now difficult for us to understand the opposition to railways in the early days. Vast sums were spent to defeat the schemes in Parliament. The most eminent Parliamentary lawyers were retained by wealthy opponents to examine and brow-beat the promoters and their engineers. The landed aristocracy, together with the canal and stage coach proprietors, engaged scientific men to demonstrate, with the aid of mathematics, that railways were chimerical and that a locomotive engine could not travel faster than eight miles an hour; and when George Stephenson affirmed that a speed of fifteen miles an hour was entirely practical, he was greeted with shouts of derisive laughter, and his sanity was seriously questioned. When the charter for the Liverpool and Manchester Railway was finally granted, and before a stroke of practical work had been done, the legal expenses alone amounted to £27,000. After stupendous construction difficulties had been overcome, the road was opened in 1830. The success of this railway was brought about by Stephenson's locomotive engine "Rocket," which won the prize at the great Rainhill contest in 1829. This engine possessed all the essential parts of the modern locomotive, but we may not discuss this matter here, except to emphasize a fact which must not be forgotten, namely, that this historic engine, which is now in the Victoria and Albert Museum, London, was the cause of a change in the economics of civilization, the magnitude of which cannot be overestimated.

The first week's business established the success of the Liverpool and Manchester Railway beyond question. The company expected to earn £10,000 a year from passenger

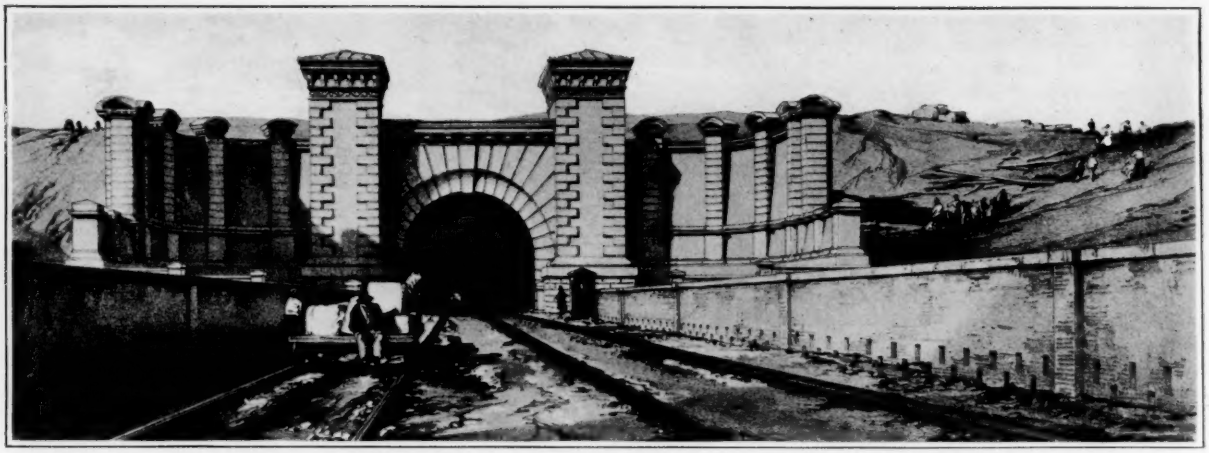


FIG. 2. TUNNEL UNDER PRIMROSE HILL. THIS TUNNEL WAS THE SUBJECT OF A MEDICAL EXAMINATION FEB. 20, 1837

traffic. The first year's receipts were £101,829. Freight was expected to give £50,000. It gave over £80,000. There was then a "boom" in railways, and capitalists began to think that there was money in this new field of enterprise. The Stephensons, father and son, quickly became popular, and were overwhelmed with applications for their services to construct new railways. The commercial classes soon became eager for a participation in the very thing which they had formerly derided, and, among numerous projects, the proposal to connect the great manufacturing city of Birmingham with the metropolis was now considered practical.

Before going further, we must note that the first idea of this railroad was brought forward in 1825, but was abandoned; and another introduced to Parliament in 1826 was thrown out. A third scheme was similarly treated in 1830; but the opening of the Liverpool and Manchester line gave a stimulus to railway projection, and a bill for the construction of a line between Camden Town and Birmingham was presented to Parliament. It passed the Commons, but was thrown out by the Lords in 1832. It was again brought forward in the following year and received the Royal assent on May 6, 1833.

George Stephenson was offered the appointment of chief engineer, but for various reasons he declined it, and the directors then decided to invite his son to fill the position. Robert, who was then 27 years of age, accepted the appointment with the understanding that his father would coöperate with him as consulting engineer.

At that time Camden Town, where Charles Dickens lived when he was a boy, was a remote suburb of London, and it was subsequently deemed advisable to extend the line to a more central position near Euston Square, the present terminus of the London and Northwestern Railway. Permission was obtained for this in 1834, which made the distance from London to Birmingham 112½ miles.

In all undertakings there is more or less difficulty in making a start, and it is now almost impossible to form an adequate idea of the mental and physical strain under which the early engineers accomplished their (to them) gigantic tasks. They worked literally day and night, and were nothing if not original. The engineer of today has his material made to order. Much of it is ready-made. Structural steel may be bought by the train load. All that is needed is to get out specifications and the material cut to dimensions is delivered on the ground. Engines, boilers and special machinery for every class of work are in the market for sale. The modern engineer cannot scheme anything that cannot be made. On the other hand, Brunel built bridges of absolutely original design and both he and his contemporaries, the Stephensons, while developing new ideas, were constantly asking themselves whether that which they wanted could be made. Could a truss be built to support loads hitherto unheard of? Could a cylinder of a given size be cast? If so, could it be bored to a uniform diameter for its entire length? Could a boiler be made to stand a pressure of 90 pounds per square inch when 75 pounds was considered dangerous? The foundryman, the machinest and the boiler maker would answer "No" to each question. Workmen were dull and slow, and the early engineers had to pull off their coats and show their men how to make things. Brunel and Gooch spent one Christmas day in a blacksmith's ship forging an experimental exhaust steam nozzle for locomotives.

Lathes had no tool rests and the tool was fixed in a ponderous iron bar, planted on the ground, steadied by the workman's foot, and held to position by the operator's physical strength. Milling cutters were unknown, and planing machines scarcely more so. Some of the old locomotives were made in blacksmith shops.

In the midst of all these distractions the opposition of the land owners had to be coped with. Public meetings were held in all the counties through which the line would pass, the project was denounced and strong resolutions were recorded against it. Although Robert Stephenson was weighed down by a multitude of cares, he was ordered by the directors to interview some of the more obdurate enemies of the railway in the hope that a call from "our eminent engineer" would placate them, but he was seldom successful. In describing one of these visits he said "We called upon Sir Astley Cooper, the eminent surgeon, in the hope of overcoming his aversion to the railway. His country house at Berkhamsted was situated near the intended line which passed through a part of his property. We found a courtly, fine-looking, old gentleman of very stately manners, who received us kindly and heard all we had to say." Sir Astley finally dismissed Stephenson and his companions with these words, "Your scheme is preposterous in the extreme. It is of so extravagant a character as to be positively absurd. Then look at the recklessness of your proceedings! You are proposing to cut up our estates in all directions for the purpose of making an unnecessary road. Do you think for one moment of the destruction of the property involved? Why, gentlemen, if this sort of thing be permitted to go on, you will, in a very few years, *destroy the noblesse!*"

New troubles came when a survey of the line was attempted. The land owners were vigilant and posted their servants, sometimes game keepers with shotguns, to obstruct the surveyors, and some of the levels were taken at night by means of dark lanterns. The London property owners were nearly as troublesome, for at that time the vicinity of Euston Square was a fashionable quarter, and the residents would not allow the surveyors to enter their back gardens or mount the roofs of their outbuildings. By various subter-

fuges, more or less amusing and sometimes dangerous, a survey of the whole line was at last completed, and in the course of his duties Robert Stephenson walked the whole distance between London and Birmingham upward of twenty times.

Settlement with the land owners was ultimately arrived at, they agreeing to accept £750,000 as compensation for their property that had been originally estimated at £250,000. The total expense of carrying the Bill through Parliament was no less than £72,868.

Ground was broken in 1834 and eighty miles of the line were shortly under construction, when further difficulties for the engineers quickly developed.

The works were let to contractors who were, for the most part, new to such business. Tools and machinery were imperfect and nearly everything was done by hand. There was no system of economizing time. Every one from the chief engineer down to the pick and shovel man had much to learn. The plans called for a double track road with easy grades, the maximum being 1 in 330 (except the Camden Town incline) for the tractive power of the old locomotives was very low; consequently, miles of deep excavation had to be carried on in order to form a level road from valley to valley through the intervening ridges, and there were many tunnels. Here, however, Robert Stephenson's experience in the coal mines rendered him good service; but even he, with all his practical knowledge, could not foresee the serious obstacles which confronted him in quick succession.

All the estimates were too low. Thus, the estimate for rails and their accessories was £213,000; they cost £460,000. Instead of wooden ties, the rails were laid on stone blocks costing £180,000. These were a dead failure, and after a short trial were replaced by wooden ties. It is interesting to recall that the locomotive is an offshoot of the stationary engine, and, as the latter was always built on a stone foundation, so, by the persistency of the human mind, it was thought that the locomotive engine required support on similar material.

Details of all the construction work of this unique railroad cannot be given here, so we will briefly describe some of the more important, beginning at the London end.

The aristocratic residents of Euston Square and Regents Park objected to locomotives, and it was therefore decided to haul the trains from Euston to Camden Town by cable traction. Two stationary engines of 60 horsepower each were built underground where the railroad crossed the Regents Canal, about a mile from the Euston terminus. Each engine moved an endless rope 7 inches in circumference and about 13 tons in weight. The ropes ran over pulleys placed in the center of the two tracks for trains coming from Euston, the up-grade being 1 in 60 and 1 in 75. On arriving at Camden Town, the trains were taken on by locomotives. Incoming trains ran into Euston by gravity. When the cable system was put to work, the residents made a further objection to the noise caused by the rattling of the ropes and pulleys.

Fig. 1 shows the line in course of construction September 17, 1836. The bridge is under Park Street, Camden Town, about three-fourths of a mile from Euston Square. Just beyond the bridge is a view of the open country toward Chalk Farm, where the first sod was cut June 1, 1834. The whole of this region and for many miles beyond is now a densely populated quarter of London. Note the primitive dumping wagons drawn by horses and the absence of all the mechanical appliances now commonly used for such work. The retaining walls were of brick with concrete backing, and were built with curved outlines obtained by the use of the batter frames as shown. The walls were a splendid piece of work, but the wet clay soil subsequently gave trouble, and transverse overhead girders had to be laid between them to keep them apart. It will be noticed that the excavation is for a four-track road. The reason for this was that the directors of the Great Western Railway proposed to connect with the London and Birmingham Company's line at Kensal Green, about four miles from Euston, which was to have been a joint terminus for the two roads. The plan was abandoned by reason of a dispute between the two companies as to their respective rights of using the tracks. The Great Western Company then acquired the necessary land and diverted their line from Kensal Green to Paddington at the west end of London. This left the London and Birmingham Company with a four-track road from Camden Town to Euston which they had no use for until many years afterward.

A few blocks south of the scene pictured in Fig. 1 the rail-

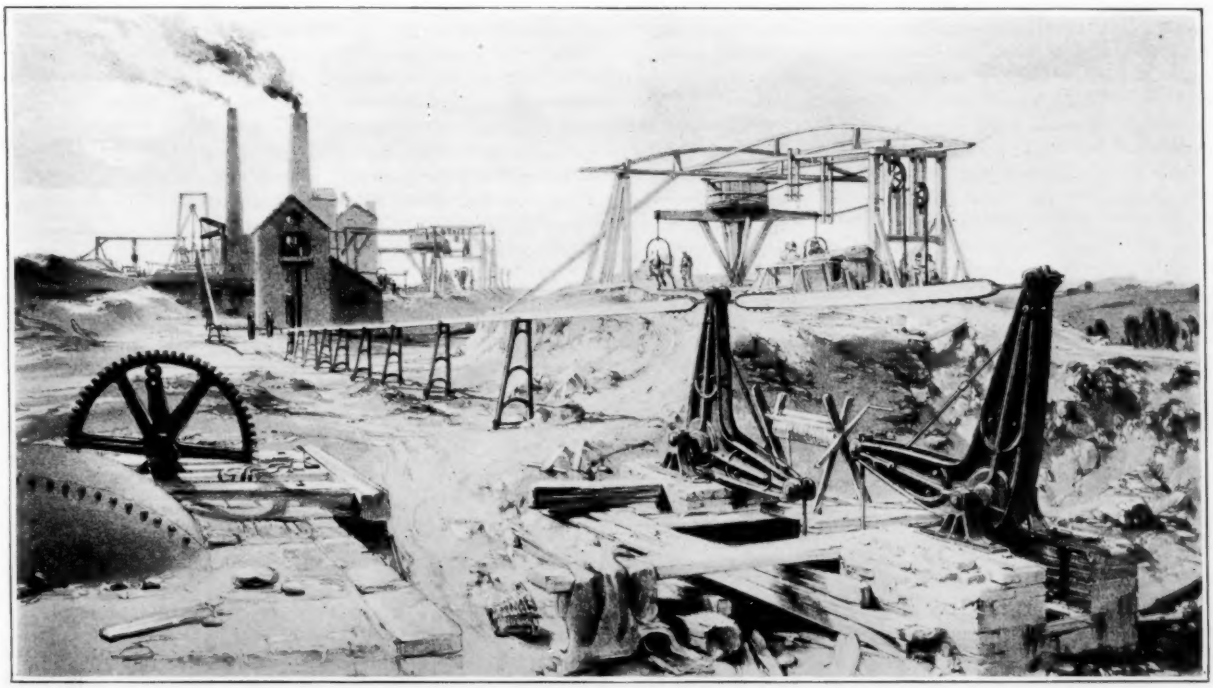


FIG. 3. PUMPING MACHINERY FOR DRAINING THE KILSBY TUNNEL

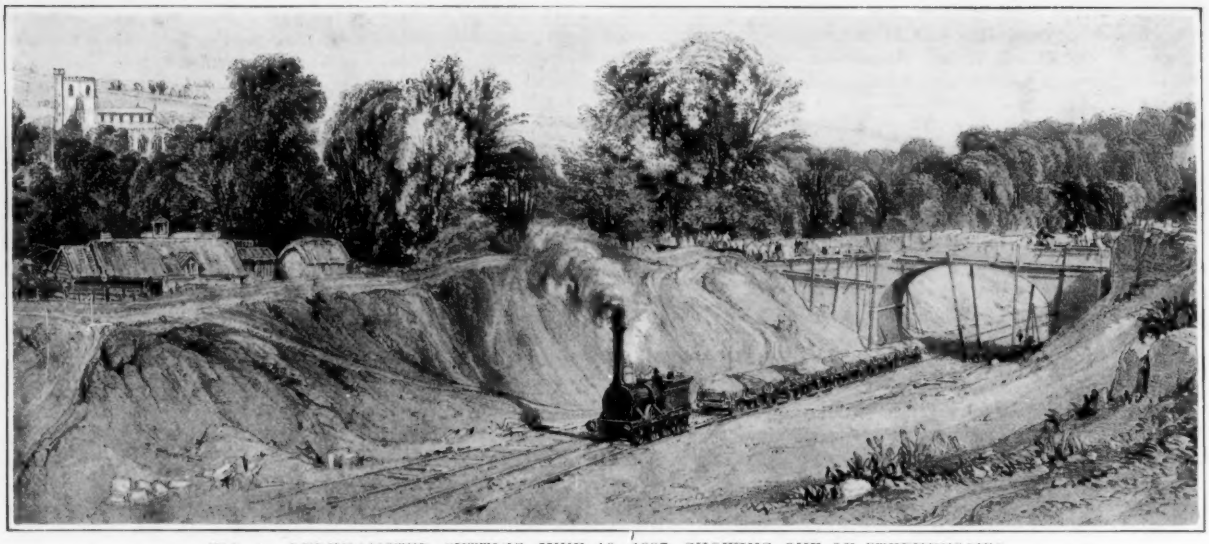


FIG. 4. BERKHAMSTED CUTTING JUNE 10, 1837, SHOWING ONE OF STEPHENSON'S CONSTRUCTION TRAINS

road passes under the Hampstead Road, near which was the "Wellington House Academy" where Charles Dickens went to school in 1825. It was partly demolished by the railroad, and, quoting Dickens's words "had its school room sliced away by the Birmingham Railway when that change came about." Dickens took much interest in this railroad and in the sixth chapter of "Dombey and Son" he gives a description of the neighborhood between Euston and Chalk Farm and the state of chaos into which it was thrown by the construction work of which our illustration gives but a faint idea.

The next important work was the Primrose Hill Tunnel, the handsome portal of which is illustrated in Fig. 2. It passes through the stiff London clay which was close, compact and dry—more difficult to work than stone itself. The clay was entirely free from water, but its absorbing properties were such that when exposed to the air, it swelled rapidly. Stephenson informed Samuel Smiles that the pressure behind the brick work was so great that it made the face of the bricks to fly off in minute chips, which covered the engineer's clothes while he was inspecting the work. It was finished without accident. To illustrate the primitive way of moving construction material, attention is called to the small flat car carrying a few blocks of stone and drawn by one horse.

This tunnel gained some notoriety as a subject for medical examination, which is amusing to us now, when subterranean travel is a part of our every-day lives. One of the many weapons in the hands of opponents of railways was the awful danger of traveling underground. Aside from the risk, medical gentlemen were strongly of the opinion that these noisome caverns would produce a train of diseases and shock to the nervous system, especially dangerous to ladies in a delicate state of health. To combat this prejudice, the railway directors arranged for a visit of experts in a special train to the tunnel on February 20, 1837. The party consisted of doctors of medicine and lecturers on chemistry. After a careful examination, their report, in part, was as follows: "We found the atmosphere of the tunnel dry, of an agreeable temperature and free from smell. The lamps in the carriage were lighted and in our transit inward and back the sensation experienced was precisely that of traveling in a coach by night between the walls of a narrow street. We are decidedly of opinion that the dangers incurred in passing through well-constructed tunnels are no greater than those incurred in ordinary traveling upon a turnpike road, and that the apprehensions which have been expressed, that such tunnels are likely to prove detrimental to the health or inconvenient to the feelings of those who may go through them are perfectly futile and groundless."

One cannot avoid the impression that this sudden and complete change of opinion on the part of the scientists was induced by favorable conditions, physical or otherwise, "arranged" by the directors.

There were eight tunnels between London and Birmingham, but we have space to notice only one more. It presented difficulties that would be serious to modern engineers, but to the men of the early thirties they were well-nigh insurmountable, and were conquered only by British tenacity and perseverance. This tunnel is at Kilsby, about 80 miles from London, and is 2,423 yards long, running at an average depth of 160 feet below the surface. Previous to letting the contract, trial shafts were sunk which indicated that the ground consisted of shale of the lower oolite, and the work was let accordingly. Soon after starting, it was discovered that between the two trial shafts, about 200 yards from the south end of the tunnel, there existed an extensive quicksand under a bed of clay 40 feet thick, which the borings had escaped in a most singular manner. At the bottom of one of these shafts the excavation and building of the tunnel were proceeding, when the roof suddenly gave way, a deluge of water burst in, and the workmen with the utmost difficulty escaped with their lives. They were only saved by means of a raft on which they were towed by one of the engineers, swimming with a rope in his mouth to the lower end of the shaft, out of which they were safely lifted to the daylight.

The work was immediately stopped; and the contractor who had undertaken the job, though he was relieved by the company from his engagement, took to his bed and soon after died.

As the pumping engines were not powerful enough to make any impression on the water, the question arose whether the works should be proceeded with or abandoned. Robert Stephenson sent for his father and the two took serious counsel together. George was in favor of pumping out the water from the top by engines erected over each and every shaft. Robert concurred in that view, but other engineers pronounced the plan impracticable and advised the abandonment of the enterprise. The directors nevertheless decided to go on, and the largest steam pumps available were then ordered. In the mean time Robert conceived the idea of running a shaft along the heading from the south end of the tunnel, with a view of draining off the water, and the drift was proceeded with immediately. When the excavators had nearly reached the quicksand there was a sudden roar as of distant thunder. It

was hoped that the water had burst in and the sand bed would thus drain itself off. Instead of which very little water appeard, and on examining the inner end of the drift, it was found that the loud noise had been caused by the sudden discharge into it of an immense mass of sand, which had completely choked up the passage, preventing the water from draining off. Numerous additional shafts were then sunk over the line of the tunnel, at the points where it crossed the quicksand, and the engines were erected and put to work.

Fig. 3 shows how these pumps were operated by means of transmission rods supported by numerous reciprocating arms. The rods were connected to bell crank levers operating the pumps below, and were driven by engines erected in houses at a distance. There were twelve steam engines operating pumps in eighteen shafts, and they pumped day and night for eight months before the water began to abate. The excavated soil was brought to the surface by horse whims, each one consisting mainly of a large drum, winding and unwinding a rope simultaneously, so that as a loaded bucket was drawn up an empty one was lowered alternately. Two of these whims are shown in the illustration.

Thirteen hundred workmen then proceeded with the building of the tunnel at several points. Every one labored constantly. The eight-hour day had not then been thought of, and men took a real interest in their work. In times of emergency they would toil for twelve and even sixteen hours, with only short intervals for meals. It often happened that the bricks were scarcely covered with cement, ready for the setting, before they were washed quite clean by the streams of water pouring from overhead.

The original estimate for the Kilsby Tunnel was £99,000, but by the time it was finished it had cost over £300,000. Robert Stephenson reported that nearly all the contractors for the tunnels on this railway either failed or were helped through by the company.

The cuttings and embankments were little less heavy and difficult than the tunnels, but we may notice only three of them.

Twenty-eight miles from London was the village of Berkhamsted, its quiet beauties remaining undisturbed until certain trespassers came tramping over the fields and crashing through the woods. Some carried chains and others bore curious instruments mounted on tripods. This was a party of surveyors and engineers headed by Stephenson. In due time they were followed by an invading army of stalwart laborers with picks, shovels and wheelbarrows. These men had an insatiable thirst and, by the law of demand and supply, temporary beer houses were opened expressly for their accommodation. Prohibition was unknown. They made night hideous with singing, roaring and fighting. The village of Kilsby had a similar experience. When a gigantic trench had been cut through the beautiful woods and deer park a new horror made its appearance. This was a fiery steam engine on wheels, with a screaming whistle audible for miles around, and dragging forty strange looking wagons loaded with earth. No one had ever seen such a thing before, and farmers left their crops to gaze on it. Animals strongly objected to it; and whenever it came along horses and cows ran for their lives, followed by pigs squealing with terror. This was one of Stephenson's construction engines, and is shown in Fig. 4, reproduced from a sketch taken June 10, 1837, with a road bridge in course of building. Close to the railroad here was the residence of Sir Astley Cooper previously alluded to.

A noteworthy example of embankment is delineated in Fig. 5, sketched June 28, 1837, at Wolverton, 52 miles from London. Here the line traverses the valley of the Ouse at an average height of 48 feet. During the work difficulties from subsidence were encountered; and the view shows a wooden trestle built over one of the landslides. The contractor failed here, and the work had to be completed by the company, giving Robert Stephenson much anxiety. The ground was composed of blue clay lias, limestone, gravel and sand, and it gave way beneath the enormous weight. When filled up, it caught fire, for in its composition was a portion of alum shale, containing sulphuret of iron. The material decomposed and ignited by spontaneous combustion. We may readily imagine the consternation of the country folk at beholding a railway on fire.

Fig. 6 shows a view of the celebrated Blisworth cutting, 63 miles from London. This lithograph was published in 1839, after the road had been opened for traffic. The cutting is a mile and a half long and in some places 65 feet deep, passing through earth, stiff clay and hard rock. One-third of the cutting was stone, and beneath the stone lay a thick bed of clay under which were found beds of loose shale, so full of water that constant pumping was necessary during construction. After a year and a half of incessant labor, the contractor had to abandon his work. Robert Stephenson then took the job in hand for the company; two locomotives were put on, one at either end of the cutting, to haul away the excavated material. Eight hundred laborers were kept busy digging, wheeling and blasting. Twenty-five barrels of gun powder were exploded weekly, and by the time the blasting was finished three thousand barrels of powder had been used. The bed of rock which overlaid the clay had to be supported by retaining walls which had not been built when the picture was taken, but one of the temporary timber supports may be seen on the left. The bridge in the distance has a span of 63 feet and its abutments rest on the solid rock sides of the cutting. The stone blocks supporting the rails are clearly shown. As previously noted, they were a costly failure.

FIG. 5. FILLING IN A LANDSLIDE, WOLVERTON EMBANKMENT, JUNE 28, 1837

In the distance is a "mixed" train hauled by two of Stephenson's locomotives. The open freight cars are at the rear of the train. The original lithograph shows two men riding on the top of the last passenger coach. These are the "guards" in charge of the train. It also shows the passengers' baggage piled on the roofs of the coaches, but these details do not come out clearly in the half-tone cut. In the early days there were no baggage cars, hence the necessity of stacking passengers' luggage on the roof. Sometimes it fell off and was lost. At other times it was stolen in transit. The man standing by the track and holding a flag is a railway policeman. These men guarded the company's property, acted as signalmen, and were ready to assist the movement of trains. They had power to arrest trespassers, and a heavy fine was inflicted if any unauthorized person was caught walking on the track.

The first portion of the railway from London to Boxmoor, 24 miles, was opened in July, 1837, and in September, 1838, the line was opened throughout. From a copy of the original timetable it appears that the fastest train covered the distance from Euston to Birmingham in 5 hours 37 minutes. The present-day trains make the same run in 2½ hours.

We will now consider the rolling stock of this historic railroad. If we could see the engines and cars today they would look like toys. Fig. 7 shows the engine which hauled the first passenger train to Birmingham July 20, 1837. This locomotive weighed but 11 tons. The cylinders were 12 inches in diameter by 18 inches stroke. Driving wheels 5 feet 6 inches diameter. The boiler was lagged with wooden staves painted green and bound with bands of polished brass. The domed fire-box was covered with polished copper, giving the engine a bright and attractive appearance. The freight engines were of the same design, but weighed about 13 tons. Sometimes five engines were required to pull a long train. We may note in passing that many of our modern locomotives weigh over 200 tons.

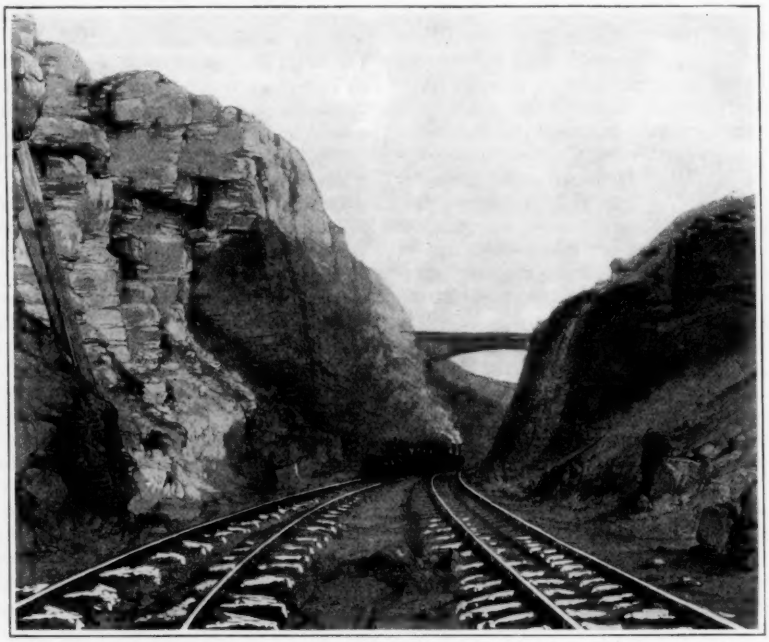


FIG. 6. ROCK CUTTING AT BLISWORTH, 1839. RAILS LAID ON STONE BLOCKS

The first-class passenger cars were comfortable, but so small and niggardly in head room that an incautious entering passenger would strike his hat against the door lintel. The second-class cars had hard wooden seats and very small windows. The third-class cars were amazingly bad, and known as "open trucks"; for they were without roofs, and the unfortunate passengers were blinded by dust and cinders, choked in tunnels and some even died from exposure in cold or wet weather, as umbrellas could not be held up in the rushing wind. *Punch* said some good things about these cars, and one wag called them "pig boxes." The comparison was not inapt, for as animals were carried in open cars, about the only difference was that swine were not provided with seats as were the human passengers. Certainly, hogs in transit are better housed today, for they do have a roof over their heads. This shameful treatment of poor people unable to pay the higher fares, was a disgrace to England.

The objection to railway traveling by the richer classes was so great that the more opulent and exclusive patrons were, on payment of extra fees, allowed to ride in their own carriages carried on flat cars, called "carriage trucks." These cars had shallow sides, but the ends were open. The writer has seen some of these shortly before they were broken up, but the railroads discontinued them in the early fifties, as they were both dangerous and inconvenient.

Charles Dickens has described this way of traveling in "Dombey and Son," and it may be noted here that although Dickens was not an engineer nor a technical man of any sort, his keen insight and ability to describe what he saw, enabled him to accurately picture objects and appearances of which he had no professional knowledge . The ordinary reader would pass over these passages, but by technical men they are well understood and appreciated. This is one of the many examples of the marvelous powers of observation possessed by the great novelist.

If the reader will refer to "Dombey and Son," twentieth chapter, he will find a good description of the journey from London to Birmingham by Mr. Dombey and his friend, the redoubtable Major Bagstock. This trip was taken, not in a railway car as the average reader would suppose, but in Mr. Dombey's family chariot. The Major's Indian servant (commonly known as "The Native") had previously packed in the carriage all sorts of requirements for the journey and when all was ready Mr. Dombey and his military friend took their places inside with the Native and Towlinson (one of Dombey's servants) in the rumble behind. On arriving at Euston the occupants alighted and Dombey and the Major walked up and down the platform side by side. There was a working man near the engine who touched his cap every time they passed. The engine was of the same design as shown in Fig. 7, and the period of the story was about the year 1844 when the rope traction was superseded by locomotives. This man was Mr. Toodle, the fireman of the engine and, as his wife had been wet nurse to little Paul Dombey, lately deceased, the honest fellow thought that Mr. Dombey would favor him with a friendly word, and introduced himself as the man who would "have the honor of stokin' of your down, Sir." He was mistaken, and the merchant prince gave "this presumptious raker among coals with cinders in his whiskers" a curt dismissal.

We will now look at the rear end of the train and we find that in "the bustle of preparation at the railway" the horses have been unharnessed from Mr. Dombey's carriage and were probably taken care of by Towlinson. The railway porters then pushed the carriage up a ramp on to the flat car above described. The wheels were then blocked and fastened to the floor and two cross bars were bolted to the car's shallow sides, firmly bracing the front and rear wheels. These operations took time and the printed rules of the company prescribed that

"Carriages should be at the station a quarter of an hour before the time of departure." The porters then lined up, touching their caps in expectation of the usual tips, although by the aforesaid rules, gratuities were strictly forbidden, and the great merchant with his military friend entered their exclusive conveyance. The step of a road carriage was higher than that of a railway car and Dickens describes how the heavy Major was hoisted into the Dombey chariot by his servant. This long-suffering foreigner then resumed his seat in the rumble. The train was probably the "Fast Mail," leaving Euston at 9:30 A. M., arriving at Birmingham at 2:30 P. M. with an average speed of about 22½ miles per hour, with occasional spurts of 50 miles an hour on favorable grades. We may imagine this primitive express train, weighing between 40 and 50 tons. On the locomotive is Mr. Toodle with a piece of new crape round his oilskin cap in loving memory of little Paul. He is firing his engine with coke, as the local residents object to coal smoke. The little engine has all it can do to pull the train up the hill to Camden Town. On the last car of the train is Mr. Dombey's chariot, with the proud and silent owner abstractedly listening to the anecdotes of "tough old Joey B. Sir." The carriage being higher than a railway car the pitching and swaying are magnified. In fact, some people traveling this way suffered an attack of sea-sickness. Mr. Dombey would be far more comfortable in a railway car, but Dickens knew that the great man would never travel in a public conveyance. In the rumble is the unfortunate Native (currently believed to be a prince in his own country) exposed to the full force of wind, dust and cinders. When he gets into the Kilsby Tunnel he will be wet to the skin. Dickens observed this aqueous tunnel at a glance, thus—"A ray of light upon the wet wall shows its surface flying past like a fierce stream."

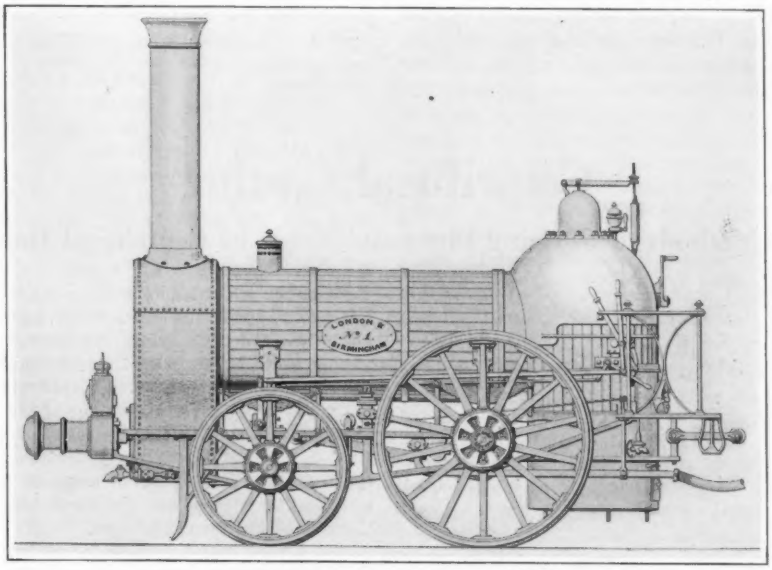


FIG. 7. FIRST PASSENGER LOCOMOTIVE, 1837

Although the locomotives were so small, their appearance at night was more impressive than that of modern engines, provided as these are, with closed ash pans under the fire-grates, and spark arresters. In chapter fifty-five of "Dombey and Son" we have a fine description of an express train at night: "A trembling of the ground; a distant shriek; a dull light advancing, quickly changed to two red eyes and a fierce fire dropping glowing coals; tracked through the distant valley by a glare of light and lurid smoke, and gone!"

The average reader, if he gave it any thought, would wonder how red lights could be seen on an approaching engine, as they are always placed at the back of the last car. The explanation is simple if we know that on some early railroads it was the practice with trains traveling at night on a single track to carry two red lamps on the front beam of the engine. One of these lamps appears in Fig. 7, which also shows at the bottom of the fire-box, the ends of the three cross bars for supporting the fire-grates. The violent motion of the engine would thus scatter the red hot fuel along the track. There were no spark arresters and the boilers were very short, so that at high speed the draft drew fire out of the chimney. If the locomotive burned coal, a dull red flame would appear. If the engine was a coke burner the flame would be of a ghastly blue color. Sometimes the base of the chimney got red hot. To remedy this defect, Stephenson designed his "long boiler engine" which is familiar to all students of the locomotive.

In looking back on the history of railway construction and working—of which the foregoing notes are a mere fragmentary sketch, we are compelled to admire the creative genius and indomitable perseverance of the men who originated and carried out the system of transportation which we are enjoying today. We may agree with John Bright, who in the course of a speech in the House of Commons said: "Who are the greatest men of the present age? Not your warriors, not your statemen; they are your engineers."

In 1846 the London and Birmingham was amalgamated with the Liverpool and Manchester and several other short lines under the title of the London and Northwestern Railway Company, and it was at this period that the great "Railway Mania" came to its height, for the reasons which will now be briefly described:

At this distance of time it is difficult to understand the wild enthusiasm of the public over railways, unless the mental eye is focused by some knowledge of the conditions which led up to it. Speaking generally, the birth of the railway was an event unparalleled in the history of the world. It is doubtful if anything like it will happen again. People were stunned by the new means of travel. Clergymen complained that instead of attending church their people flocked to the railroad "to see the trains go by." Imagine the transition from a stage-coach jolting over rough roads at 10 miles an hour to a train rushing along a smooth track at 40 miles an hour or more! And this all within a year or two from the opening of the Liverpool and Manchester Railway. Again, the Liverpool and Manchester and the London and Birmingham lines paid dividends of 10 per cent. The Stockton and Darlington Railway paid 15 per cent. Money was cheap and remunerative, investments were scarce. With these facts in mind we begin to realize why people lost their mental balance, and capitalists, great and small, plunged recklessly into this new investment. The Stephensoss with George Hudson (the leading railway financier) were subjects of hero-worship; and kings esteemed it an honor to shake hands with them. The railway was recognized as "the greatest civilizer of the age." Railway pictures were sold in print shops. Cups and saucers were embellished with paintings of Stephenson's locomotives, and pocket handkerchiefs were similarly decorated. Tailors' shops exhibited trousers made of gray mixture cloth into which were woven parallel black lines in groups of four. This was "The Railway Pattern" and very popular with the young men of the period. In concert rooms "The Railway Gallop" was a favorite number on the program. It was cleverly orchestrated and really effective. Starting very slowly, the speed and volume of sound with the constant beat

of the engine gradually increasing until it reached "50 miles an hour," with occasional long or short bursts of thunder from the drums to suggest tunnels and bridges. All this sounds childish today, but it was a very real thing in the early forties.

No railway scheme was too wild for investors, and contemporary prints show crowds of promoters with great rolls of plans under their arms, besieging the offices of the British Board of Trade. During the years 1844-5-6 no fewer than 440 bills were passed by Parliament authorizing the construction of 8,470 miles of railroads and the raising of new capital to the amounnt of £180,138,901. In contrast to the old Parliamentary opposition, bills were passed practically as presented. It is estimated that £100,000 per week was spent in advertising new lines, some of them running parallel with each other. When the advertisements appeared shares were instantly applied for, and in many cases large premiums were paid for the mere chance of allotment. Some of these competing lines were never built and others that were built never paid interest. Even a line from Paris to Pekin was considered a probability.

Some far-seeing men sought to discourage the craze by ridicule, but of course without effect. A sarcastic writer proposed issuing a prospectus inviting subscriptions for "The Great North Pole Railway, forming a junction with the Equinoctial Line, with a branch to the Horizon." Another writer remarked that if such an advertisement was ever published subscriptions would, doubtless, be forthcoming. He was not far wrong, for the title of some of the projected lines were grotesque, embracing the names of towns and hamlets of absolutely no commercial value. *Punch* in 1846, published a prophetic railway map of England. It looks like a conglomeration of spiders' webs.

Wild schemes for the construction of 600 miles of railways in the county Lancashire alone at a cost of £15,000,000 sterling were advertised, and £1,250,000 were immediately subscribed. In every case lines of speculators were found in the street outside the promoters' offices, and the police were required to keep order. When the doors were opened there was a mad rush for position, and many fights ensued, during one of which the secretary's table was overturned and the clerks fled in terror.

A few level-headed financiers gave repeated warnings of the inevitable outcome of building unnecessary competing lines, but nobody heeded them. Vast sums of money disappeared and were never accounted for, and in due time came the crash, bringing ruin and misery on countless numbers of people.

For some of the notes embodied in the present article the writer is indebted to Smiles' "Lives of the Engineers." His thanks are due to Sir Gilbert H. Claughton, Bart., chairman of the London and Northwestern Railway Co., for courtesies extended, and the valuable assistance of Mr. W. B. Paley, the noted railway historian of London, is also gratefully acknowledged.

Centrifugal Casting

Various Methods of Forming Pipes and Tubes by Centrifugal Deposition

THE following abstracts from recent technical periodicals were gathered by *Mechanical Engineering* and published in the July, 1921, issue of that journal. They give an excellent review of recent progress in this interesting method of casting:

NON-FERROUS CASTINGS IN SPINNING MOLDS

Description of a method for casting copper bands for large Navy shells by a centrifugal casting machine process as used at the works of the George C. Clark Metal Products Company, Detroit.

The process appears to be one which requires a high grade of skill and knowledge at practically every stage, beginning with the handling of the metal, it would appear that positive methods must be employed that will permit the band to be cast at the most desirable temperature; as otherwise the physical properties of the compound will not be right.

The metal is cast in down-draft melting furnaces of 3,000-pound capacity each, and from the furnaces is poured into ladles of a capacity suffifficient for three bands. It is hauled to the casting room by means of an overhead trolley system and extra precaution is taken that the metal does not oxidize on its way to the casting room.

The principal parts of the casting machine are the die and die holder, the movable spout and the metal-pouring attachment. The holder is made of plain carbon steel wire, the die or liner is a specially heat-treated forging. A hinged cover plate of the same diameter as the holder and having an opening large enough to accommodate the pouring spout is made to open and close on the side of the die and holder. It is said that the life of a liner is such that about 250 bands may be cast before it is burned out and replaced.

It is obvious that all revolving parts must be in absolute balance, as otherwise the band will not come out true. The metal is poured through the spout so arranged that it can move in and out of the die. Pouring is done by tilting the small crucible in the machine so that the metal will flow through the spout into the die. While the machine is still in motion the spout and crucible are pulled back out of the way and when the band shows the desired color for annealing, a stream of water is turned on the band. After the band has solidified sufficiently and has received the proper annealing, the water pipe is taken back out of the way, the cover plate is unscrewed and the band removed from the die. After the band is cast, it is necessary to keep the lip of the pouring spout clean, as a certain amount of metal clings to its side and has to be removed by hand with a chisel. The bands themselves are then machined.

It is stated that the most successful bands made are of the larger diameters, 10 inch and up, and that the percentage of rejected castings made by this process is small. Louis J. Josten in *The Iron Age*, Vol. 107, No. 20, May 19, 1921, pp. 1289-1292.

CENTRIFUGALLY CAST CAST-IRON PIPE

Description of the DeLavaud process of centrifugal casting of cast-iron pipe as carried on commercially in Canada.

The pipe is cast on the inside of a horizontal water-cooled rotating cylinder revolved on its axis by an impulse water-wheel integral with itself and flared at one end to give the proper contour to the bell. The mold revolves in a cylindrical stationary casing and is supported at two points in its length by two pairs of friction rollers which are carried on the inside of this casing. In the manufacture of 6-inch water pipe, the speed of revolution is about 550 r.p.m.

The molten metal is introduced into the mold by a cantilever spout, which receives its supply from a tilting ladle operated by hydraulic pressure. The iron for the bell end is first supplied, immediately following which the casing and mold are moved backward by hydraulic means on horizontal ways away from the ladle and spout, thus enabling the latter to supply the metal continuously from the body of the pipe right out to the spigot end. The mold continues to rotate for perhaps 15 seconds after the last of the necessary iron has been supplied.

As it comes from the mold the iron is chilled and must be annealed. This annealing in a special furnace takes from six to seven minutes, after which the pipes are allowed to cool in still air.

Centrifugally cast pipes are lighter than sand mold pipes of similar bore, and, for example, in 4 inch size the standard C class weighs 23.3 pounds per foot and the centrifugal pipe 15 pounds.

The metal in centrifugally cast piping is of a dense homogeneous character and the pipes are smooth inside and out. Tests were carried out by the writer at the University of Toronto on pipes and pipe material made by sand casting and spinning and it was found that roughly the tensile strength of specimens from centrifugally cast pipe was 2.3 times as great as that found for specimens cut from sand mold pipes. In every other test the centrifugal modulus of elasticity was 2.3 times greater for machine-made pipe than for ordinary pipe, and a 6-inch pipe with walls 0.28 inch thick was found capable of sustaining an internal hydrostatic pressure of 1,250 pounds per square inch without failure.

The pipe is manufactured in Canada by the National Iron Corporation, Ltd., Toronto.—Prof. Peter Gillespie, of the University of Toronto, in *The Canadian Engineer*, Vol. 40, No. 19, May 12, 1921, pp. 454-455.

STEEL TUBE CASTING

Description of a process for the centrifugal casting of pipe in which the metal is melted electrically in the same mold in which it is subjected to the spinning process.

The process is carried on in four stages, the first consisting of casting the metal in bars of approximately the same weight and length as the final tube. These bars, together with such additional metal as is necessary, are placed into the mold which consists essentially of an outside steel shell, a refractory lining and a graphite lining. The molds with the metal inside are closed air-tight at both ends and placed in a rack where electric current is supplied to the terminals from a bus-bar. They are left on the rack until the metal inside has thoroughly melted, and are then transferred to the spinning machine.

The spinning continues until the metal has solidified, the time varying with the kind of metal and to a certain extent with its external temperature. When the metal in the tube has set, it is allowed to cool until the contraction of the diameter of the tube is sufficient to pull it out of the mold. It is then subjected to such heat treatment as may be necessary.

The advantages claimed for this process are its practically automatic character permitting the use of unskilled labor, and, simultaneously, ability to control very strictly the temperature and combustion of the metal and also the absence of gases in the mold.—*The Iron Age*, Vol. 107, No. 20, May 19, 1921, p. 1300.

HUME CENTRIFUGALLY MADE CONCRETE PIPE

Description of a process for the manufacture of concrete pipe by centrifugal deposition as carried out by a company in South Africa.

The pipe is reinforced with steel and the first step in its manufacture is the preparation of the reinforcement. As the plant is located not far from the gold mine district of Witwatersrand, it is able to make use of the reinforcing elements of discarded mine haulage cables.

As the cables are delivered at the pipe works in coils, they are first degreased, which is necessary, as cement will not adhere to any material that has a greasy surface. The grease is burnt out by wood fire, the wire being somewhat annealed at the same time.

After the coil is cooled down it is unraveled with the help of specially designed motors. This is followed by spooling the cable, the spools being then transferred to the machine on which the reinforcement cylinders are made.

The spool of wire is placed on a spindle set vertically and fixed a few feet from the machine. The end of the wire is drawn forward and threaded through a series of three pulleys on a traveling feeder, these pulleys serving to keep the wire tight. The feeder itself is part of the reinforcement machine, along the base of which it is drawn by means of chains in a direction parallel with the cage core.

The reinforcement or "cage" is built on a round horizontal core consisting of four readily collapsible sections.

The molds are two-piece cylinders made of galvanized iron and are greased inside to prevent the cement from adhering. The reinforcement is then inserted and the end caps bolted in position. These end caps are broad, flat rings, the inside diameter of which is the inside diameter of the pipe to be made, the desired thickness of the pipe wall being exactly secured by the use of rings or end caps of the proper dimensions.

The pipe-making machines each make six pipes in one operation, the duration of which may be anywhere from 12 to 20 minutes, according to the size of the pipe.

In making the concrete for light-pressure pipe, Pretoria cement is used with sand and specially selected ¼ to ½ inch grit, in the proportion of 2 to 2 to 1; for high-pressure pipes sand and cement are used in the proportion of 2 to 1. The material is prepared in rotary mixers from which it is discharged into a pair of barrows traveling on a pair of rails underneath the pipe machines.

The speed of the pipe machine during the process of shoveling the concrete into the rotary molds is set slow and all the workman has to do is to throw the concrete rapidly, a shovelful at a time, into the mold. When the molds have received enough concrete the speed of the machine is increased (this speed varies with the size of the pipe and, for instance, for a 4-inch pipe, it is 360 r.p.m., while for a 6-foot pipe it is 48 r.p.m.).

One of the important features about the Hume pipe is the great denseness of the material. The following tests have been made to prove this. An ordinary 12-inch mold without reinforcement was filled with concrete and rammed in by hand as tightly as it would go. In other words, the same process was followed as one might use to make a solid concrete column. The mold was then placed on the machine and rotated at the speed required for the making of an ordinary Hume pipe. After that, the mass was examined and was found to have developed itself into a pipe with an internal diameter of 3½ inches, which would mean that the 12-inch column, as originally made, had a volume of air-filled spaces between particles equivalent to a pipe 3½ inches in diameter and that by the centrifugal action this was packed solid.

The pipe has also a rather unusual joint. The end of each pipe is so molded that instead of a flat surface a groove of a peculiar shape is produced, this groove being such that its deepest portion lies toward the inner periphery of the pipe while it becomes shallower as it reaches the outside periphery. When two pipes are brought together, their edges enclose a cone-shaped space, the apex of the cone being toward the outside of the pipe and this space is filled by the pipe layer with a special plastic compound.

A sleeve of concrete also goes over the joint and its inside diameter is a little larger than the outside diameter of the pipes. The annular space thus formed is filled with a mixture of sand and cement, which is caulked or rammed into position exactly as lead is used for joining iron and steel pipes. The practical effect of this system of jointing is that the greater the pressure of water in the pipes, the more resistant to leakage becomes the joint.

A claim is made that the Hume pipe never bursts and that when the pressure is increased beyond a certain point the pipe merely begins to "weep." If the pressure is further increased sprays of water appear, but there is no burst and not only that, but that when the water pressure is reduced to normal the pipe is just as efficient as it was before. In other words, the strain does not cause any deterioration.—*The South African Journal of Industries*, Vol. 4, No. 3, March-April, 1921, pp. 224-235.

The Super-Conductivity in Metals*

Experiments in Electric Conductivity at Low Temperatures by Kamerlingh-Onnes

By C. A. Crommelin

UPON various occasions it has been observed that the variation of the electrical resistance of metal wires differs greatly at high temperatures from the variation at low temperature. It frequently happens, *e.g.*, in the case of platinum that the temperature co-efficient diminishes sharply with a fall in temperature; at times a break has been found in the curve which represents the resistance as a function of temperature. Naturally, this observation aroused the question as to how electrical resistance would behave in the immediate vicinity of the absolute zero.

An opportunity to make investigations along this line presented itself to Kamerlingh Onnes at the University of Leyden, after he had succeeded in 1908 in liquifying helium and in almost attaining the so-called absolute zero, *i.e.*, minus 273 deg. cent. by the aid of this liquified gas.

Starting from the electron theory of electrical conductivity in metals Lord Kelvin came to the conclusion in 1902 that at the absolute zero the resistance must be infinitely great. His theory was that the degrees of dissociation of the electron would be nil at the absolute zero and that free electrons, in so far as they were still present would lose their power of motion, or, as Kamerlingh Onnes has expressed it, the electrons would condense like a vapor upon the metal atoms and freeze fast to them.

Up to that time it had not been found possible to confirm this theory by means of experiment. The minimum which was expected in the resistance curve was not found even at the temperature of liquid hydrogen (minus 253 deg. cent. to minus 259 deg. cent.). But with the help of liquid helium it became possible to carry on investigations in the immediate neighborhood of the absolute zero. At ordinary atmospheric pressure helium boils at about minus 269 deg. cent. and at a pressume of 3 mm. of the mercury column it boils at a temperature of minus 271.5 deg. cent.

The first experiments were made with a wire composed of pure platinum 0.1 mm. in thickness, whose resistance had already been determined at the lowest temperature of liquid hydrogen and which it was now attempted to find at the temperatures of liquid helium. The wire was wound upon a small glass cylinder, the ends being fused in the glass and soldered to long copper wires connected with a Wheatstone bridge. This coil of wire was placed in a glass vessel capable of being cooled by liquid helium. We will refrain here from giving a more exact description of this highly complicated apparatus, which we shall refer to merely as a cryostat and shall content ourselves with relating the results of the experiments thus made.

The results of even the first measurements made were highly surprising as is evident from the figures in accompanying table. In this table the temperatures are given in so-called *Kelvin* degrees, *i.e.*, they are counted upward from the absolute zero, 0 deg. cent. corresponding to 273 deg. K.

Thus we see that there is not a trace of the minimum which Lord Kelvin's observation had led us to expect—on the contrary, downwards from 4.3 deg. K. throughout the whole temperature range of the helium, there was exhibited a very slight and quite uniform resistance.

This entirely unexpected result suggested to Onnes that perhaps the resistance of perfectly pure platinum would be nil at the absolute zero and that the constant residual resistance observed might be caused by the traces of impurities which always cling to a platinum wire produced in the usual manner. In order to test the correctness of this idea the measured resistance of gold was graphically extrapolated in the helium range. This extrapolation made it appear very probable that the residual resistance does, indeed, proceed from impurities. The accuracy of this extrapolation was then tested by measurements at the helium temperature. It was found that the resistances of gold containing a known quantity of impurities likewise exhibited a residual resistance—and the greater the contact of foreign matter the greater this residual resistance. This leads us to believe that the resistance of both pure gold and pure platinum differ very little if at all from nil at very low temperatures. While this conclusion is not final it is very convincing to the effect that the above mentioned theory of Kelvin must be given up—indeed, the experiment proved most convincingly that there can be no question of an infinite increase in the resistance.

The investigation was next directed towards the experimental support of the concept of the becoming nil of the resistance in an absolutely pure metal. But unfortunately metal wires of such absolute purity as required by the experiment could not readily be obtained since the very act of drawing them always contaminates them. It is possible, however, by distilling quicksilver in a vacuum to obtain it in much purer form than other metals; mercury was accordingly selected. It was placed in a capillary tube bent into a zig-zag form and having a diameter of about 0.005 mm. Ordinarily, when mercury is frozen its particles fall asunder. To prevent this a special device was employed, which consisted in attaching small mercury containers to the upper part of the capillary tube.

Table 1

ABSOLUTE TEMPERATURE		$\frac{W_t}{W_o}$
273.09 deg. K		1.0
20.20	liquid H_2	0.0171
14.20		0.0135
4.30	liquid H_e	0.0119
2.30		0.0119
1.50		0.0119

W_t = measured resistance.
W_o = resistance at 0 deg. cent.

Now when the mercury wire is slowly cooled from bottom to top, the mercury container furnishes mercury as the mercury wire contracts and thus prevents the breaking of the thread of quick silver. In this manner it finally became possible, after many fruitless attempts to produce mercury resistances of sufficient magnitude to meet the demands of the experiment (*e.g.*, 172.7 Ohm at zero deg. cent.). But the enormous amount of trouble and labor which was required to accomplish this was richly rewarded by the results of the experiments thus made possible. The resistance proved to be immeasurably small at the temperature of helium; the most remarkable thing noted, however, was the fact that the resistance down to a position shortly below 4.2 deg. K. suddenly dropped from a measurable amount to a value practically nil. The temperature at which this happens is called the *spring point temperature*. A measurement of the resistance (so far as this still exists) below 4.2 deg. K. was no longer possible; it was

*From an address published in the *Chem. Weekblad*, Amsterdam, 1919, p. 640. Translated for the *Scientific American Monthly* from the German version in *Die Naturwissenschaften* (Berlin), for Jan. 28, 1921.

only possible to establish the fact that, for example, at 2.45 deg. K. $Wt/Wo < 2 \times 10^{-10}$. This condition of apparently infinite conductivity has been called by Kamerlingh Onnes, *the state of super-conductivity.*

All sorts of questions at once presented themselves as a result of this discovery: Is the resistance really nil in the state of super-conductivity or is it merely exceedingly small? Is it still correct to speak of a resistance and in such case does Ohm's law hold good?

It has not as yet been possible to answer all these questions in a statisfactory manner, but during the course of the experiment a great many remarkable phenomena were observed, which go far toward explaining the essential nature of the state of super-conductivity. In an experiment made to see whether heat was developed by an increase of the strength of the current in a super-conductive mercury wire, it was found that for any given mercury wire it is possible to speak of a boundary value of the current for any given temperature, below which limit no development of heat is to be observed. In some wires it is possible to increase the current up to 1200 amperes per sq. mm. without any difference of tension between the ends of the wire being observable and without the wire's return to a state of normal conductivity. Above this boundary value heat is suddenly developed and the wire then loses its property of being a super-conductor. Whether we have to deal here with the ordinary Joule heat throughout the whole wire caused by the circumstance that even in the state of super-conductivity there is still a residual resistance left or with heat which is developed at only at the imperfect parts of the wire, and which passes from there throughout the whole of the infinitely conductive wire, could not be established with certainty; it was quite certain, however, that the heat did not proceed from the conducting wires or inlet wires. Kamerlingh Onnes was of the opinion that the bad parts of the wire were the probable cause of the development of heat. The only objection to this view is the regularity with which the phenomenon occurs. But whatever its origin this residual resistance which still remains even in the condition of super-conducitvity is termed by Kamerlingh Onnes the *Micro-residual-resistance.* It was further observed that the boundary value fell with the temperature, and that the spring point (or saltation point) varies with the strength of the current, *i.e.*, that the greater the current the lower it is, a fact which is probably to be explained by the usual development of heat. Finally, it was proved that Ohm's law holds good above the spring point.

It is not possible here, of course, to enter into detail with respect to the very difficult and extensive measurements made. If we seek the origin of the micro-residual-resistance in the presence of impurities, then we must come to the conclusion, that impurities are responsible, as in the case of the gold and must further conclude that the "pure" mercury contains only one-millionth part the amount of impurities present in the "pure" gold. But it is difficult to accept this view. When in this connection an attempt was made to compare mercury with gold and for this purpose to carry out measurements with mercury which had been strongly adulterated purposely with gold or with cadmium the surprising observation was made that even this very impure mercury was super-conductive in nature.

After the mercury, *lead and tin* were examined. Tin was fused in a vacuum and then poured into a capillary glass tube. At the temperatures of helium it was super-conductive and its spring point lies at 3.78 deg. K.—lower, therefore, than the spring point of mercury. But the spring point of lead appears to be much higher. At hydrogen temperatures lead is still normally conductive and does not become super-conductive until the helium temperatures are reached. Its spring point was found to lie too high to be ascertained in liquid helium (presumably at about 6 deg. K.). It is noteworthy that amalgamated tin, whose spring point lies at 4.29 deg. K. becomes super-conductive at a higher temperature than do its constituents, tin and mercury.

Besides mercury, lead, and tin, several other metals have been studied, especially in order to find out whether it is possible to discover metals which still possess a sufficient temperature co-efficient in liquid helium, in order to render it possible to make use of them as resistance thermometers at the lowest temperatures. This investigation which was, however, merely directive in character showed that *iron, cadmium,* and *copper* possessed a resistance in liquid helium which remained uniform; this resistance is, therefore, apparently to be regarded as a residual resistance, as in the case of gold and platinum, and that on the other hand the constantan and manganin alloys possess a sufficient temperature coefficient and may thus be expected to prove suitable for the making of resistance thermometers.

From all of these investigations we are justified in concluding with great probability that there are still other metals to be found which exhibit the state of super-conductivity, but whose investigation will undoubtedly be attended with great difficulties because of the fact that it is exceedingly hard to obtain these metals in a perfectly pure state.

Another possibility which has occurred to Kamerlingh Onnes but which has not yet received a practical test, is of interest. This concerns the *production of very strong electro-magnetic fields.* It is theoretically possible to obtain a field of unlimited strength, provided only that we can introduce a sufficient number of ampere windings without a core about the space in which the field is to be created. In actual practice we can obtain a strength of field of 100,000 Gauss by means of wire coils which have been proved with liquid air, but it is calculated that on account of the quantities of liquid air which would be required to absorb the Joule heat developed, the cost of the air would be about that of a battleship. But the matter would be very different, if we could employ a wire coil composed of a super-conductive metal. As we have already said, it is possible to send a current of 1200 amp. per sq. mm. through a wire coil of mercury, or a current of 560 amp. per sq. mm. through a coil of super-conductive lead without causing the wire to lose its super-conductive character and without any Joule heat being developed, provided only that we are careful to allow no radiated or conducted heat to reach the wire, so that the strength of the current remains below the boundary value.

It is a peculiar fact, too, that there is no trouble in winding such a coil upon metal provided that the metal itself is not super-conductive. Indeed, an ordinary metal actually behaves like an *insulator* with respect to a super-conductive metal. There is no doubt at all that with a super-conductive coil of about 30 cm. diameter, and with the aid of the Leyden helium apparatus and its appendages, a magnetic field of 100,000 Gauss could be attained at a very low cost.

Because of the well-known phenomenon that the resistance of many metals is augmented as soon as they are brought in to a magnetic field Kamerlingh Onnes made the attempt to see whether the magnetic field also exerted an influence upon the super-conductivity of metal. The test was made with tin wire and lead wire; in the case of both metals *a resistance suddenly appeared as soon as the field had reached a certain degree of strength, and the wire thereupon lost its property of being super-conductive;* the strength of field required to produce this effect, however, is not the same for different temperatures. Thus we see that the introduction of a magnetic field has the same effect as the heating of the wire, and it is possible, therefore, to speak of a boundary value in the case of the magnetic field likewise.

A remarkable experiment.—This brings us to the point where it is proper to describe an especially notable experiment intended to show the duration of the current in a super-conductor—an experiment which cannot, indeed, be said to have revealed any actually new principle, but which, nevertheless, had results so surprising that but a short while ago their mere possibility would have been beyond the dreams of men.

A small closed coil of lead wire was used, consisting of 1,000 turns of 1/70 sq. mm. section and a resistance of 734 Ohm at

ordinary room temperature. Its relaxation time, *i.e.*, the time required for the current produced in such a coil by induction to disappear is calculated to be 1/70,000 sec. The micro-residual resistance was estimated to be at 1.8 deg. K. only $\frac{1}{2} \times 10^{10}$ part as great as at the temperature of the room and the relaxation time must correspondingly amount to, at least, a period of one day at 1.8 deg. K. The experiment was carried out in the following manner: The coil was put in the cryostat and the latter was then placed between the poles of a very large electromagnet, the surface of the windings being perpendicular to the lines of force, so that the coils thus embraced a bundle of lines of force. After a magnetic field having a strength of 400 Gauss had been produced and the coil had attained a state of super-conductivity, the field was reduced within a space of about 10 seconds to a strength of 200 Gauss, and the magnet was then removed after a lapse of about 5 seconds. The number of lines of force surrounded by the coil were reduced within a short space of time, to approximately zero, by which means an induction impulse was produced in the wire and a current excited. The electromagnetic effect of this current was determined by means of a magnetic needle placed at a short distance from the cryostat.

The earth magnetic field was compensated by means of a skilfully placed steel magnet. *The result proved that the induced current really remained in a state of circulation;* naturally, the strength of the current could not be measured in this manner, it was possible to prove, however, that it amounted to about 0.6 amp. still falling, therefore, below the boundary value of 0.8 amp. which had been provided for in the preliminary preparation for the test. Naturally, too, it was not possible to reach a boundary value for the magnetic field, since in this case the wire would have become normally conductive and the current would have disappeared in a short time. It goes without saying that a phenomenon so surprising as this was carefully verified by means of control tests and by a change in the conditions of the experiment. The measurement of the current was also corrected by the magnetic needle, so that it was possible to obtain a degree of accuracy of approximately 2 per cent. In this manner it was finally determined that the decrease in the strength of the current amounted to less than 1 per cent per hour, from which it followed that the time of relaxation must amount to more than 4 days.

If we assume that the micro-residual resistance obeys Ohm's law (which is, however, as we remarked above, by no means certain), we find that in the case of lead this resistance amounts to only a fraction of the resistance at the ordinary temperature, *i.e.*, from 1/0.3 times 10^{-10} to $1/0.2 \times 10^{-10}$.

But in order to remove every doubt as to whether the observed electromagnetic field might not proceed from the brass mounting of the wire, coil, as to whose magnetic properties at the temperature of helium, no previous knowledge was possessed, Kamerlingh Onnes performed the following ingenious test: Both ends of the wire in the lead coil were soldered to each other in such a manner that they could be torn apart inside of the cryostat at a given point by means of a wire hook operating from outside. On both sides of this breaking point a wire was soldered which led to a ballistic galvanometer. After a continuous current had been induced in the coil the wire was torn asunder. This forced the current to follow the path leading through the galvanometer so as to occasion therein a ballistic outward thrust. As a matter of fact at almost the same moment that this outward thrust was produced, the current had ceased because of the circumstance that an ordinary resistance was now introduced in the circuit. From the outward thrust, just mentioned, it was calculated that a current of about 0.3 amp. had passed through the lead wire.

CONCLUSION

In conclusion let us describe another experiment which was carried out at the suggestion of Professor Ehrenfest; this suggestion was to the effect that a thick ring of lead might be substituted for the numerous windings of the wire coil; it was believed that the induced continuous current must, under such conditions, be capable of becoming very strong, and this prediction proved to be correct. A current of 320 amp. with a density of 30 amp. per sq. mm. (the density in the coil equalled 49 amp.) was detected; it remained constant for a half hour at less than 1 per cent.

Kamerlingh calls these continuous currents in super-conductive metal *imitations of ampere currents.* Ampere was led by the discoveries made by himself and by Oerstedt with respect to the connection between magnetism and electricity to formulate the hypothesis that the field in the vicinity of a magnetic body is produced by a number of exceedingly small circular currents which flow undamped in or around the molecules and that magnetization consists merely of the bringing of these molecular currents into a parallel direction. This hypothesis rendered it possible to ascribe the property possessed by para-magnetic bodies to the effect produced by electric currents. The theory of electrons is, likewise, based essentially upon this concept, in the special sense, of course, that in this case the electric currents are conceived of as consisting of electrons revolving within the atom.

Even in the time of Ampere, however, some doubt was cast upon this hypothesis of *undiminished currents possessing no resistance,* because of the fact that no *example* of such a thing was known. It is all the more remarkable to think that we are now capable of imitating the hypothetical molecular currents of Ampere's concept by the experiments just described with ordinary metal wires. In this connection we may also mention briefly the sensational experiments made in 1915 by Einstein and W. J. de Haas: By means of an extremely ingenious apparatus these experimenters succeeded in proving experimentally that the molecular currents or revolving electrons really exist in a permanent measure; thus the ancient hypothesis formulated by Ampere again holds a place of highest honor.

TECHNICAL EDUCATION IN THE SOUTH

THE unique methods employed by those interested in the future of the Georgia School of Technology to interest the state in the proper support of that institution deserves some note.

Last autumn a distinguished group of Georgians headed by the Governor and the president of the Georgia School of Technology made a tour at their own expense to various industrial and educational centers of the North to see first what was being done there in providing facilities for technical education and, secondly, in what way the raw materials of Georgia entered into the manufactured products of those communities. They were deeply interested in the use made of Georgia clay sold for a few dollars a ton in Georgia in the production of our highest grade pottery and like utilization of many Georgian minerals and other raw materials. They were encouraged to find graduates of Georgia Tech in many high positions and went home determined to provide better facilities for the education of more Georgians and boys of the South generally, and better commercial opportunities for the employment of these boys once graduated.

In April these same men toured their state for a week, visiting more than thirty towns and cities, to recite to the stay-at-homes what they had seen on their northern trip and to impress upon them the necessity of providing more adequate support for the school at Atlanta. Notwithstanding the present industrial conditions, particularly in a state where cotton plays an important part, the prospects are encouraging and those interested in the direct support of a state institution by the citizens as contrasted with appropriations from legislatures are watching developments with unusual interest and hoping that the full program laid down will be realized at an early date.

Scientific Methods of the Paris Police

How Ingenious Modern Methods Are Made to Serve the Ends of Justice

By Jacques Boyer

Illustrated with Photographs by the Author

WHILE it would seem that the number of murderers, thieves, and forgers in our modern world is constantly on the increase and while they appear to be daily becoming more intelligent as well as the possessors of more dangerous weapons and more diabolic tactics, on the other hand, our corps of police and our judicial experts are fully keeping pace with them. Crafty and bold as our "gallows birds" may be and well informed as they are with respect to the scientific methods employed by the police in the detection of crime, our agents of the law are skilled in tracking down and arresting these evil doers —often at the risk of their lives. They succeed in identifying criminals as well as in detecting crime, by means of preliminary operations begun upon the very spot where the latter were committed. They do this by means of skilled specialists and by a careful study of the minutest clues uncovered by minute examinations of the scene of the crime.

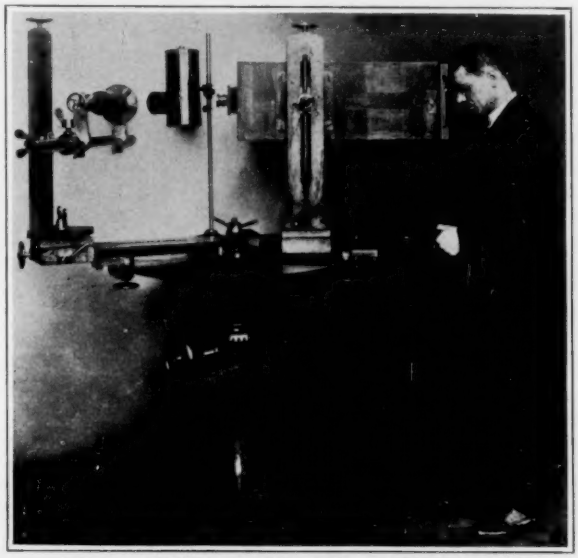


FIG. 1. CAMERA MOUNT FOR PHOTOGRAPHING FINGER PRINTS

The Bureau of Judicial identity which was created in 1883 by Alphonse Bertillon confined itself for a long time to the identification of habitual criminals by means of photographs and anthropometric measurements. Then upon the demand of the Bar "the official photographer of Messrs. Les Attaches" changed his profession into that of a photographic reporter of a special sort. Bertillon and his disciples extended their endeavors to the photography of localities where crimes had been committed and to taking impressions left by criminals upon objects in or near the scene of the crime.

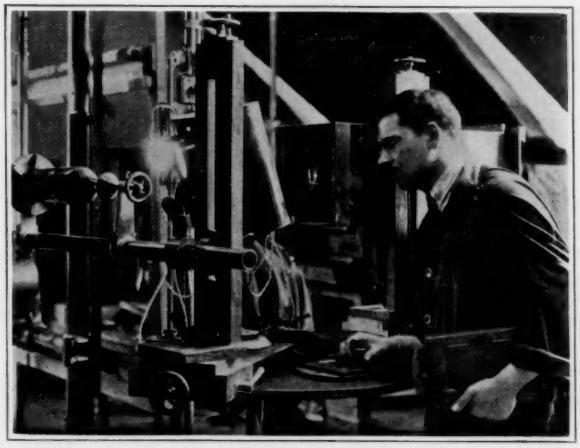


FIG. 2. PHOTOGRAPHING FINGER PRINTS ON A BOTTLE
(Note method of illuminating the object)

Little by little the horizon of the science of "Bertillonage" has extended itself until the modest studio where human measurements were made, has been transformed into a *scientific laboratory of police*, and this laboratory has gained tremendously in importance since it has been presided over by M. Bayle, who is not only a scientific criminologist but a chemist having highly original ideas. This savant was called to be the chief of the bureau in 1915, and he has developed expert judicial methods in the application of physics and chemistry to the detection of crime.

This peerless analyst and his remarkable collaborators possess in most cases only the most infinitesimal *traces* or *clues* upon which to base reports enabling the judges to come to correct decisions—they may have a few drops of a suspicious liquid, an imperceptible spot, minute scraps of clothing, a bit of hair, or a fragment of organic tissues, suffices to set them upon the path at whose other end the criminal awaits them. Even if a criminal has made use of gloves, if he has touched some object in the room where his crime was committed, the impressions which he leaves make it comparatively easy to identify him. If a "crook" has merely changed the date of a government bond by means of chemical reagents, his fraud can be detected by the difference of electric conductibility between an intact portion of the document and that portion where the erasure was made.

By making a microphotographic study of a bit of dust, taken from the edge of a hatchet, an expert can state positively whether the accused owner has wiped the edge of his tool with a bit of rag or with a scrap of newspaper, whether he has killed a human being with it or merely chopped a piece of salt meat in two.

Again, a photograph made by ultra violet rays will show whether the wax seals on a parcel sent by post has been meddled with while a tiny spot of paint straight from a shoelace proved indisputably that the transported criminal Almereyda had hanged himself in a cell.

But before we climb to the top floors of the Palais de Justice where the experts of the scientific police laboratory perform their daily labors let us accompany the staff of the technical section upon one of their expeditions: A crime has just been announced at the police station. A telephone call at once sends to the field a mobile brigade of the technical section (this consists usually of three photographers, a draughtsman, and a finger print expert). As soon as they have arrived at the scene of the crime they proceed to collect all the clues left behind him by the criminal, going through a series of definite processes in a methodical manner according to a *formula* dictated by the Bureau of Judicial Indentification.

The principal items in this formula are as follows: One of the investigators examines the locks of the doors and windows before the party enters while his colleagues photograph the ensemble of the room where the crime was committed and the body of the corpse. Meanwhile, the draftsman draws the plan of the room or of the apartment. When examining the corpse of the victim the staff is directed to describe any disorder of the clothing, any peculiar spot or marks upon the linen and to take a sample of the victim's hair, noting the exact spot from which it is taken; the apparent cause of the death must also be set down with any peculiarities in connection with it, etc. In a strangling case, for example, the observers must endeavor to discover whether the deed was accomplished by a hand or by a cord, and in the second case the latter is brought along together with all connective data. Nothing is left to chance.

We may note especially the peculiar care taken with regard to the directions laid down with respect to blood spots; these include tests made upon the spot with peroxide, location and enumeration and statement of the forms taken, whether in the form of drops, spurts, streaks, pools, smears or wiped up places. Especial care is taken likewise with respect to the observation of foreign substances such as bits of hair, bone, brain matter, etc.

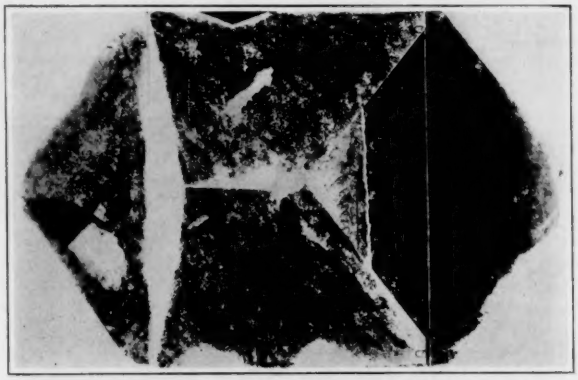


FIG. 3. PRINT BY TRANSMITTED LIGHT OF AN ENVELOPE SHOWING THAT IT HAD BEEN OPENED BEFORE THE SEALS HAD BEEN AFFIXED

The most infallible method of identification employed today is by the examination of finger-prints. In consequence of this the inspectors must examine with the greatst care furniture, panes of glass, drinking glasses and bottles, or pieces of paper which may have been touched by the criminal. But when such objects are removed the inspectors must be careful to grasp them in a manner impossible for the criminal to have grasped them. In the case of a bottle, for example, it is lifted by placing the forefingers in its neck and the other fingers on the bottom, great care being taken not to touch its side. When broken glass is to be removed it is picked up by the sharp edges, while a drinking glass is lifted by catching the bottom and the edge between the four fingers and the thumb *without touching the sides.*

In order to transport objects marked with finger-prints to the laboratory, a specially constructed chest is employed in which broken panes of glass, bottles and glasses may be held between adjustable bolts and studs so as to prevent all friction of surfaces covered with authentic "criminal signatures." Finger prints on walls, looking glasses, trunks, and large pieces of furniture are copied on the spot in the following manner: After the print has been colored either by blowing lead carbonate upon it, if it is on a dark background or by lamp black or powdered graphite if it is on a light background, the excess of the white or black powder is removed with a very delicate brush and a photograph of the impression is then made.

Let us now leave the technical section and see how the scientific laboratory of the Bureau of Police in Paris makes use of the materials collected by the members of the mobile brigade for its inspection.

Since finger prints are not very visible Mr. Bayle has had a special apparatus constructed for photographing them as shown in Fig. 1. The camera and the object to be photographed are mounted upon arms which may be swiveled about a table. The illumination consists of two nitrogen lamps (Philips) of 2,000 candlepower each (Fig. 2). By means of this system of swiveling arms the position of the finger prints with respect to the source of light can be changed at will, so as to stand

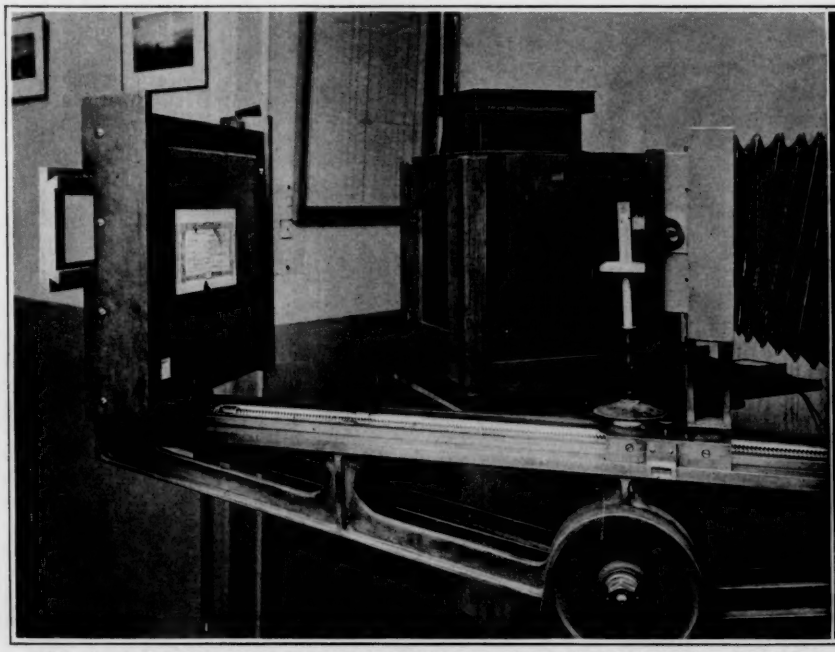


FIG. 4. APPARATUS FOR TAKING PICTURES BY ULTRA-VIOLET LIGHT. ONE OF THE TWO CASES CONTAINING MERCURY-VAPOR LAMPS IS SHOWN IN THE BACKGROUND

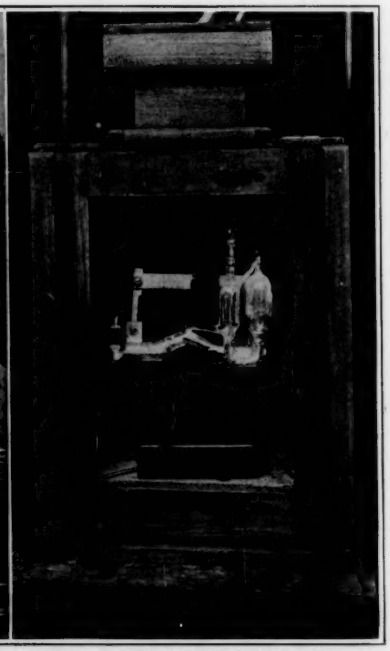


FIG. 5. THE MERCURY-VAPOR LAMP FOR PRODUCING ULTRA-VIOLET RAYS

out as strongly as possible upon the ground glass screen of the camera. The images thus obtained are irrefutable witnesses; thus the thumb prints of the right thumb of a suspected individual magnified to 5 diameters are placed side by side with similarly enlarged thumb prints from the scene of the crime. The value of this method is admirably shown by the statistics with regard to the identification and formal inculpation of 123 criminals last year.

Appeals addressed to the special section, 1,203.

Number of finger prints obtained upon the scene of the crime, 2,282.

Comparisons made, 122,205.

Total number of negatives developed, 4,582.

Total number of proofs made, 6,788.

Criminals detected by means of finger prints, 123.

The technical staff next proceeds to make as rapid an examination as possible of the clues obtained, and the results of this investigation are reported in a daily meeting under the presidency of the director of the judicial police and in the presence of the commissioners of the Quarter and the principal inspectors of public safety and of the various districts — all these receive reports of the above meetings.

But the activities of the photographic studio of the laboratory by no means cease here. As arranged by Bertillon it is in possession of a certain number of instruments of precision which serve for the reproduction of the most various documents and objects, as well as for certain researches in the domain of optical physics. (This studio must not be confounded with the Bureau of Anthropometric Measurements in which ordinary photographs, both front view and side view of criminals are taken as a matter of record.) It is in this special studio which is practically a sort of annex to the scientific laboratory of the police bureau that expert, technical, judicial investigations are carried on. Besides making microspectrographic, chemical, or biochemical analyses based upon known reaction in the examination of blood spots, M. Bayle has recently put in operation a combination of general methods fitted for the identification of the spots. In order to illustrate this highly original technique devised by him, let us select four typical examples of criminal acts which he has succeeded in solving.

FIG. 6. PHOTOGRAPH IN ORDINARY LIGHT OF A FRENCH BOND WHICH WAS SUSPECTED OF HAVING BEEN TAMPERED WITH

FIG. 7. SAME BOND PHOTOGRAPHED IN ULTRA-VIOLET LIGHT DISCLOSING THE DATE *27 AOUT 20* WHICH HAD BEEN ERASED

An envelope sealed with five wax seals was sent to the laboratory. This envelope was supposed to contain 25,000 francs in bank notes, but when opened by the recipient it was found to hold nothing but wrapping paper. In this case the rôle of the expert was confined to circumscribing as much as possible the necessary researches of the *Juge d'Instructions* by searching for clues which the thief might have left upon the exhibit. Since the wax seals appeared to be absolutely intact, M. Bayle proceeded to dissolve them in a benzo-alcoholic mixture. He then saw that the paper bore no trace of being torn underneath the seals — hence the thief had not removed them. Continuing his examination he immersed the envelope in water in such a manner as to cause the different parts of it to come undone from each other, after which he spread them out and photographed them by transmitted light. In this manner the key to the mystery was at once found. A part of the band torn off by the instrument which had opened the envelope remained glued to the other side of the fold (Fig. 3). Furthermore, there was a small particle of wax at one point of this tear, consequently, it was evident that when it was sealed, the break in the paper had already existed. Since it was also found out at what time the seals had been placed upon the letter it was an easy matter to deduce the fact that the theft had been made in the house from which the letter was sent and in the room occupied by a certain employe.

Let us turn to another instance in which the problem was solved, this time in a negative manner, by means of a microphotograph. A hatchet with a blade which had been stained in some manner and then wiped off, was sent to the laboratory with the request that an endeavor be made to find out whether it had been dried by means of a rag or by means of a piece of newspaper. A few minute fibers were found clinging to the scratches upon the hatchet and these were first colored with Selleger's (Zelleger's) reagent (iodated nitrate of calcium), and then examined under an enlargement of about 3,000 diam. This reagent stains cotton fibres a pink color and fibres of

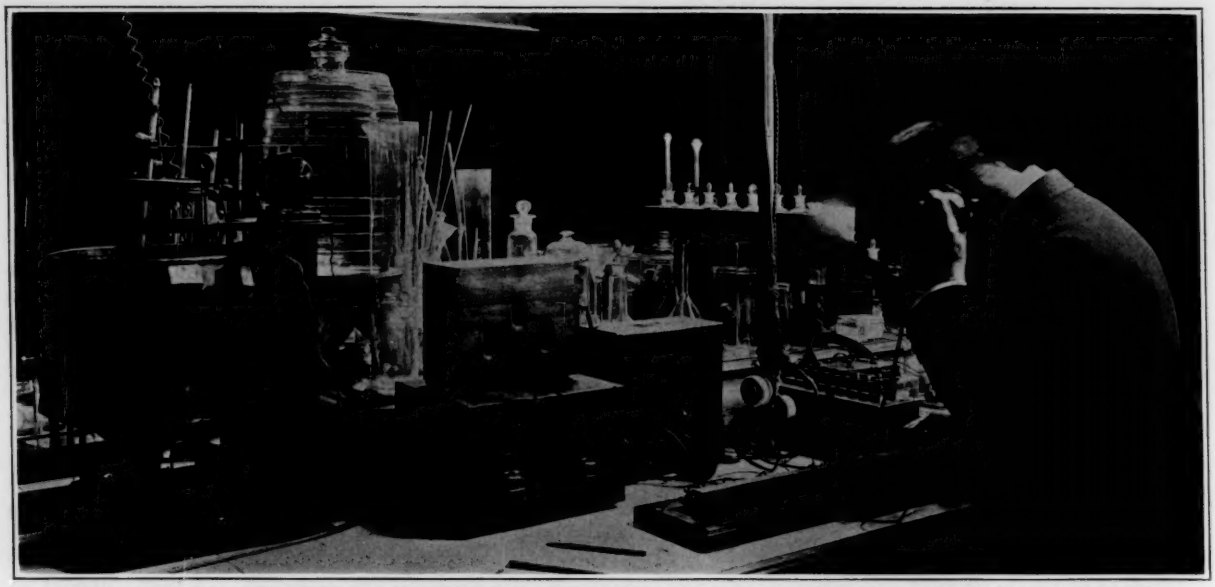


FIG. 8. SENSITIVE ELECTRICAL APPARATUS FOR DETERMINING MINUTE QUANTITIES OF CHEMICAL SUBSTANCES

newspaper (which is manufactured from wood pulp) yellow; the form of the cotton fibers also differs greatly from that of newspaper fibers. In this case only cotton fibers were found so that the examiners concluded that the hatchet had been wiped with a piece of cloth and not with a newspaper belonging to the suspected man. Finally, and this was of far more importance in establishing the innocence of the suspected criminal, the analysis revealed no trace of blood, but only a bit of moist dirt containing 80 per cent of sea salt. This showed that the suspected instrument had not been used to kill anybody but had merely been employed for cutting a brine cured ham!

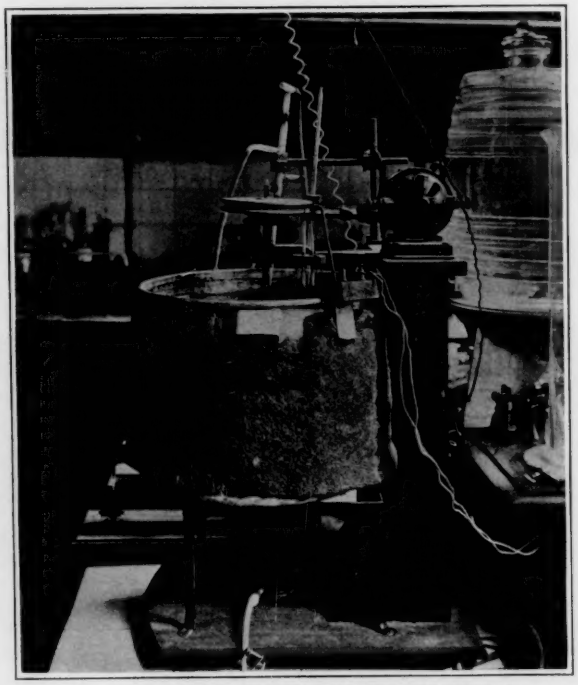


FIG. 9. CLOSE-UP VIEW OF THE THERMOSTAT SHOWN IN FIG. 8

DETECTING FORGERY BY ULTRA-VIOLET RAYS

Ultra-violet rays also furnish a means of great precision in the detection of certain cases of forgery. In the Police Laboratory the Henri George Mercury Vapor Lamp (Fig. 5) is used for this purpose because of the very powerful ultra-violet rays which it emits. It is enclosed in a specially constructed lantern and provided with a screen made of a special glass which is opaque to visible light but transparent to ultra-violet rays. It is a well-known fact to students of these rays that certain substances, such as sulphate of quinine, nitrate of uranium and the platino-cyanide of barium when exposed to them become fluorescent, while other substances, such as a spot of blood, for example, remain dark.

M. Bayle has had the clever idea of utilizing this fact as a means of detection in certain cases of crime. For example, one of these substances may be suspected of forming a portion of some article connected with a criminal case, obviously if it does form such a part its presence can be detected by the ultra-violet rays without the necessity of injuring or destroying the article in question. Although the technique of this new method of examination is not yet fully formulated, some very brilliant results obtained in this manner may be mentioned. A very striking instance was that of the theft of a million francs' worth of government bonds of the National Defence issue. These bonds had already been called in and paid when they were stolen from the French Treasury. The forger carefully erased the dates which had been written in by hand and inserted new dates, whereupon they were presented for payment a second time.

M. Bayle photographed one of these bonds in ordinary light (Fig. 7) and then took another negative by means of ultra-violet light (Fig. 6). As our photographs show the effaced date is quite invisible in the first photograph but in the second one it plainly appears as follows: *25 Aout 20*. It should be observed also that the stamp showing payment upon the date *Decembre 1920*, for which a greasy and non-fluorescent ink was employed has likewise disappeared in the picture taken by the ultra-violet radiation. In order to take negatives of this sort the Bertillon photographic apparatus (Fig. 4) is made use of, because of the fact that by a system of gearing the orientation of both the photographic plate and the document may readily be changed. The latter is illuminated by means of two George mercury lamps placed symmetrically on one side and the other of the camera. A screen interposed between the lens and the article to be

photographed absorbs all of the visible rays of the spectrum.

Furthermore, in order to determine the precise circumstances under which the theft took place the judge requested the experts of the laboratory to make an effort to determine whether there was any complicity between the person who was found in possession of the package of bonds and one of his presumed accomplices, in whose residence there had been seized a package of blotting paper covered with spots. The point to be determined was whether the substance which had made these spots was identical with the chemical solution which had been used to wash off the date upon the bond. In other words, whether at a given moment these blotters had been in contact with the bonds or lying near them. As we see this problem presents difficulties quite insuperable by the ordinary physical and chemical methods of inquiry, since it was necessary not only positively to affirm their identity, but also to state the proper amounts capable of being applied, in case one and the same liquid taken from one and the same bottle had been utilized.

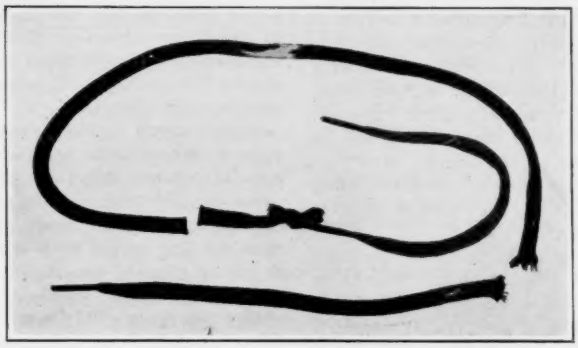


FIG. 10. SHOE STRING WITH WHICH A NOTORIOUS CRIMINAL HANGED HIMSELF

ELECTRO-CHEMISTRY AS A DETECTIVE AGENT

M. Bayle solved this problem in the following ingenious fashion by calling to his aid an electrochemical test.

The method used in this case was based upon the following ideas which are very simple in principle. When a circuit is formed comprising a battery, an alarm bell and two sheets of copper immersed in a vessel full of water the bell will sound only if a little sea salt be thrown into the liquid. Hence the quantity of electricity which passes between the two sheets of copper will indicate the weight of the salt or other electrizable substance which has been introduced into the cell, and the current will increase in strength with very great rapidity in proportion to the amounts of salt added. M. Bayle, therefore, conceived the clever idea of constructing an experimental contrivance (Fig. 8) capable of measuring the extremely minute degrees of electrical intensity thus produced and of determining in this manner the infinitesimal amounts of electrolytic substances contained in the liquid of the battery cell. For this purpose a varying resistance (Wheatsone bridge) of known quantities as small as one desires are compared to the resistance to be estimated; this is done by moving a slide which runs along a carefully calibrated platinum wire, 1 meter in length, which is stretched lengthwise along a scale graduated in millimeters.

The alternating current required is produced with all the rapidity necessary for the observations by means of a small induction coil operated by a storage battery. When the telephone bell introduced into an intermediate circuit is silent a state of equilibrium is indicated; this shows that the resistance sought is at this instant exactly equal to the opposed resistance. An audion composed of three lamps similar to those employed in wireless telegraphy, increases the sensitiveness of the method by amplifying beyond the state of equilibrium, the current by which the measurements are made. Finally, in the bath of the thermostat shown in Fig. 9 two electrodes are immersed; these consist of two small concentric cylinders made of platinum and protected by a glass case; this permits the experimenter to determine the matter with 20 drops or so of liquid. The small electric motor which appears beside the thermostat sets in motion an electric fan designed to render uniform the temperature of the water which is maintained at a constant point by means of a Bunsen burner.

In order to make a measurement after the current has been thrown into the coil, the operator takes hold of the microphone of the telephone with his left hand. He then hears it ringing and he moves the slide until he can no longer hear any sound. At this instant the resistance due to the added salt is equal to that which was to be determined, and the amount is shown by the figures upon the scale at this point.

This being clearly understood let us now see how ingeniously this method was applied for detecting the forgery in the government bonds described above. The experimenter cut out by means of a punch a circle of paper in a part of the bond where an erasure had been made, and then with the same punch he made several similar holes in intact portions of the same document, One of these "confetti" was dropped into the bath of the thermostat whereupon this minute fragment of paper containing within the substance which composed it, a trifle of soluble matter, gave up the latter to the liquid, thus modifying its electric conductivity and interrupting the equilibrium. Thereupon, the experimenter restored the equilibrium as described above by moving the slide along the platinum wire. As soon as the telephone bell fell silent again the figure upon the ruler indicated the amount of soluble matter originally contained in the circle of paper. By treating in the same manner a piece of paper of the same size but taken from an intact portion of the document, the position at which equilibrium occurred was found to be at a different point. Furthermore, under given conditions of experiment each salt yields a figure which is characteristic to itself and typical of its molecule, so that in this manner it is possible with but little work to compile a comprehensive table of molecular conductibilities.

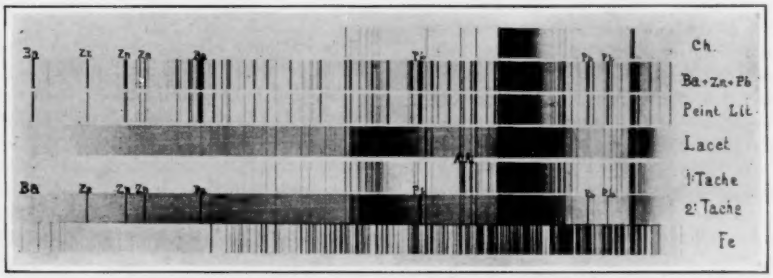


FIG. 11. SPECTRA SHOWING THAT A SPOT ON THE SHOE LACE WAS MADE BY PAINT FROM THE BED OCCUPIED BY THE CRIMINAL

If the solution used in the experiment consists of a mixture or contains impurities, these will play a part in the average conductivity and it is plain to be seen that under the given conditions, if we obtain identical figures, we are perfectly justified in forming the conclusion that the two liquids being studied are identical. In order to throw light upon the case of the bond forgeries, in question, M. Bayle was obliged to make a series of measurements upon lacerations of paper reduced to the same content of chlorine by means of titration and being sufficiently dilute for the impurities present in the paper to count for practically nothing as compared with the substance experimented upon.

A comparison of the intact areas with the areas where erasure had occurred, brought out very suggestive differences. This is admirably shown by the figures expressing the resistances in ohms of the same voltage of distilled water, in which there had been soaked for an equal length of time equal areas of the erased paper and the original document:

Circule of paper cut from the erased portion (forged)	812
First circle of paper cut from intact area	464
Second circle of paper cut from intact area	451
Third circle of paper cut from intact area	472

This table shows clearly that that part of the paper where the date had been forged exhibited a much stronger resistance —about twice as great—as the intact area of the same bond, by reason of the fact that a portion of its soluble substances has disappeared in the course of the fraudulent washings it had undergone. Sometimes, however, the contrary effect is produced because of the lack of skill on the part of the forger who had failed to wash the paper thoroughly, in which case there remains a trace of the reagent used to destroy the color, so that upon examining the area under suspicion it will be found to exhibit a smaller degree of resistance. However, since it is an ill wind that blows no one any good, according to the proverb, the figures obtained in this case serve to identify the reagent employed by the forger.

The precision of this method is so great that one ten thousandth part of a milligram can be detected by it. Thanks to its use M. Bayle was able to conclude not only that the spots on the blotters contained hypochlorite of lime (Javel water)—which ordinary chemical analysis would have revealed, but it was the *very same liquid* which had been used in falsifying the bonds.

In other analogous affairs he recognized specifically the common origin of various spots found on documents taken from various persons, thus establishing the complicity of the latter.

THE SPECTROGRAPH AS A CRIME DETECTOR

The spectrographic method of analysis has also been perfected in this laboratory. A single example will suffice to show its delicacy and we may conclude our remarks by an account of a famous case in the *Bonnet Rouge*. Upon the shoe laces (Fig. 10) of the notorious Vigo, known as Almereyda, who died very suddenly in the hospital ward of the Prison of Freynes two spots were found, one of which was much bigger than the other. The judge in charge of the case asked M. Bayle to analyze these, as is shown in Fig. 11. The skilled expert compared the spectra of the two spots, of the intact portion of the shoe lace, and the paint on the bed occupied by the criminal. He thus proved conclusively that one of the spots consisted of mud (giving an aluminum-ray), while the other possessed the rays characteristic of the paint on the hospital bed (lead, zinc, barium). It was thus found that the convict had hanged himself in his cell! A mere spot upon a shoe string was sufficient to reveal to a savant the sad end of this unhappy creature.

* * *

Let us finish our visit to the laboratory by the exchange of a few words with its young director. * * * In one of the conversations in which he revealed some of the secrets of his profession he remarked modestly: "All this is only a beginning."

As a matter of fact, we have here reported only a portion of the new processes invented by this eminent expert chemist.

PECULIARITIES OF THE HUMAN NAILS

A GREAT many animals possess claws which both assist them in walking and act as weapons of defense or offense, sometimes of a very terrible nature; likewise, they often serve in grasping their prey, but it is only human beings and certain families of apes which have *flat* nails upon their fingers and toes. It is an interesting circumstance, however, that the nails of apes and of men differ strikingly from each other in the fact that the quick of the nail is very strong in the former and very weak in the latter. Only the great toe of all apes (with the exception of the orang-outang bears nails which resemble those of man in this respect, being equally poorly provided. In fact, the nails of the "semi-apes" resemble those of man more strongly than do those of the great apes or anthropoids. According to a recent German writer, H. Friedental, whom we find quoted in the *Naturwissenschaftliche Umschau d. Chem.-Zt.* (Berlin) for Jan., 1921, remarks concerning this that practically the only difference between the nails of these semi-apes and those of man consists in the fact that the former possess a claw upon the second toe of each foot. The nails of these half apes are as slightly curved and as scantily provided with the "quick" as those of man.

Upon the hand of a human being the nail of the second finger is usually the flattest in shape, the curvature increasing in the following order: first, third, fifth and fourth. This curvature is most marked during the first two years of a child's life, being most prominent of all before birth and shortly thereafter.

With respect to the development of the breadth without respect to the curvature, the series of finger nails generally runs as follows: one, three, two, four, five. The longitudinal curvature, however, is very slight in flat nails and often not present at all in the thumb nail. Extra-European races have more strongly curved nails than any of the white races. Even in colored races of men the layer of horn is so transparent that the bed of the nail, which is poor in pigment, shines through with a red color. This is not the case, however, in apes.

The chief function of the nails is to scratch and they make excellent weapons. In digging up edible roots the finger nails of men are of as much service as those of apes. The loss of the nail greatly interferes with the more delicate functions of the fingers, whereas there is no perceptible interference with the use of the toes from such a loss. As respects its origin the flat nail can be apparently traced to a simple digging claw. This is indicated by the fact that in the man-like apes a primitive nail, a sort of primeval claw first develops above the end of the finger and is not shed until after the animal's birth. From the end of this primitive nail nearest the body, the horny plates of the secondary flat nail are developed. Furthermore, the innervation of the nail members proceeds from the lower side which corresponds with the idea that the flat nail has its origin in the base of the primitive claw at the end of the finger.

A NEW CINEMATOGRAPH LAMP

THE ordinary cinematograph lamp for currents between 30 and 70 amperes, or even up to 100 amperes, has the carbons in line, and only slightly tilted from the vertical, so that the crater of the upper carbon shall burn away in front. From 5 to 7 handwheels are fitted to permit common and individual adjustment of the carbons, so that the crater may be kept in focus, from which it is continually tending to depart. Obviously the optical conditions can be much improved by making the upper (positive) carbon horizontal, but it has hitherto been found impossible to stabilize the arc in this type of lamp with a higher current than 30 amperes.

In their new projector lamp, the Körting & Mathiesen Co. claim to have solved the problem of satisfactory burning with horizontal positive carbon using currents as high as 80 amperes. The crater being practically vertical, from 25 to 50 per cent more light is said to be projected on to the screen for equal watt consumption, and the screen is moreover uniformly illuminated top and bottom. Only three hand-wheels are necessary, one for raising and lowering the lamp vertically, one for common movement together of both carbons, and one for advancing or withdrawing the top carbon. The arc is centered by a blow-magnet. Satisfactory operation is claimed on alternating current as well as direct current. Polar curves of the new and old types of lamp are reproduced.—*Electrotechnik und Maschinenbau.* Abstracted by the *Technical Review.*

Notes on Science in America

Abstracts of Current Literature

Prepared by Edward G. Spaulding, Ph.D., L.L.D., Professor of Philosophy, Princeton University

THE EFFECT OF LIGHT ON GERMINATION

In a very exhaustive article in the *Botanical Gazette* for April, 1921, Dr. Wright A. Gardner of the Alabama Polytechnic Institute presents the results of investigations on the effect of light on the germination of light-sensitive seeds. Introducing his article, the author says:

Various explanations have been offered for the germination of light-sensitive seeds, and several conditions have been shown to favor or make possible the germination of such seeds. Rupture of coats, increased water supply, variation of quantity and intensity of light, reciprocal relation of heat and light, reaction of substratum and embryo activation of enzymes, increased oxygen pressure, increased carbon dioxide pressure, and "certain inhibiting agencies" have been suggested as factors affecting the germination of light-sensitive seeds. Although quite possible, it seems hardly probable that no one of these is the fundamental or controlling factor. It would seem rather that one or two of these agencies are fundamental and the others accessory means of setting in motion the processes that finally bring about germination. Enzyme action has been suggested repeatedly as a fundamental cause of germination, but no one has ventured to demonstrate the relation of enzymes to the germination of light-sensitive seeds.

The author's own investigations were intended to discover the fundamental relation of light to the germination of seeds, and to show just what light does to start germination. The experiments concerned such subjects as:

Germination in light and darkness.
Light sensitiveness, after-ripening, and viability.
Mechanical rupture.
Temperature and light.
Effects of alternation of temperature, light, and darkness.
Hot water treatment.
Water absorption.
Injection of seeds with water.
Increased oxygen.
Effects of electrolytes.
Lipoid solvents.
Enzymes.

Results of the investigations are summarized as follows:

1. The seeds of *Rumex crispus*, *Datura Stramonium*, and *Phoradendron flavescens* were found to be light sensitive. The germination of seeds of *Rumex crispus* and *Phoradendron flavescens* was promoted by light; the germination of seeds of *Datura Stramonium* was hindered by light.

2. Abrasion and removal of coats (ovary walls) of *Rumex crispus* seeds promoted their germination in darkness.

3. Treatment of seeds of *Rumex crispus* and *Oenothera biennis* with concentrated sulphuric acid caused an increase in the percentage of germination in darkness.

4. No reciprocal relation between the effects of light and temperature was found.

5. Light was not necessary for the absorption of sufficient water for germination.

6. Injection of water did not yield increased germination in darkness.

7. Almost all kinds of single electrolytes, regardless of the nature of the ions, seemed to promote germination of seeds of *Oenothera biennis*, *Nicotiana Tabacum*, and *Verbascum Thapsus* in darkness.

8. Embryos of seeds incubated in light became more acid than those incubated in darkness.

9. Light seemed to activate lipolytic enzymes which hydrolyzed fats to fatty acids.

10. The germination of seeds of *Rumex crispus* in darkness was promoted (increased) by hot water treatment, abrasion, treatment with concentrated sulphuric acid, increased oxygen pressure, fluctuating temperatures, and soaking in solutions of hydrochloric acid, sodium sulphocyanate, and hydrogen peroxide.

11. The germination of seeds of *Nicotiana Tabacum* in darkness was promoted by soaking in solutions of hydrochloric acid, sodium sulphocyanate, and hydrogen peroxide, as well as by the use of many single electrolytes as substrata.

12. The germination of seeds of *Verabascum Thapsus* in darkness was promoted by the action of light, fluctuation of temperature during incubation, alternating high and low temperatures, soil, and many single electrolytes as substrata.

13. The germination of seeds of *Oenothera biennis* in darkness was promoted during certain seasons by hot water treatment, sulphuric acid, preliminary incubation at low temperature, incubation in alternating high and low temperatures, and single electrolytes as substrata.

14. The germination of seeds of *Daucus Carota* in darkness was promoted by increased oxygen pressure and preliminary incubation at low temperature, while it was hindered by soaking in hydrochloric acid and by the use of single electrolytes as substrata.

THE NUTRITIVE VALUE OF YEAST IN BREAD

In the *American Journal of Physiology* for May, 1921, Messrs. P. B. Hawk, C. A. Smith and Olaf Bergeim of the Laboratory of Physiological Chemistry, Jefferson Medical College, present an interesting article on the nutritive value of yeast in bread.

"In view of the fact that bread is the chief of staple foods," the authors state "it is of importance to know whether the yeast used in its preparation should be looked upon merely as a generator of carbon dioxide or whether yeast improves the nutritive value of the loaf. If, as seems clear, yeast must of itself be considered as a food, it is of importance to know in what way it supplements the other ingredients of bread and in what amounts it should be used to obtain a product of maximum nutritive value. Also we cannot afford to underestimate the possibility of yeasts ultimately replacing in the diet certain other important foodstuffs."

It has been known for a number of years that the ash of yeast is especially rich in the important element phosphorus, containing at the same time very considerable amounts of potassium and lesser amounts of the inorganic elements essential in nutrition. Yeast also contains a considerable amount of carbohydrate, including cellulose and gum-like substances and glycogen. It is high in protein and in a nucleic acid yielding purine and pyrimidine bases, a pentose, and phosphoric acid on hydrolysis.

That yeast contains an antineuritic substance was shown by Schaumann. Hopkins first showed yeast to contain a substance small amounts of which accelerated the growth of rats fed purified foods. These observations have been repeatedly confirmed and extended until it is now generally recognized that yeast is one of the richest and cheapest sources of water-soluble vitamine.

The authors' experimental procedure was as follows:

Young male albino rats, obtained from the rat colony of the Wistar Institute of Anatomy, were used as experimental subjects, and were divided into two groups of eleven rats each. The attempt was made to have the two groups as nearly alike

as possible at the start of the experiment. The average weights for the two groups at the start were 60 and 61 grams respectively.

The rats in one group were fed white bread made to approximate closely standard home-made bread, while the rats in the other group were fed bread made with considerable extra yeast. The high yeast content was obtained by mixing 5 per cent of dried compressed yeast with flour and by using six times as much fresh yeast as was used in making the standard bread.

The results obtained showed that on the average the rats fed extra yeast bread gained 66 grams in 11 weeks or nearly three times as much as the rats fed standard bread (23 grams), average gains per week being 6 grams and 2 grams, respectively. The rats fed extra yeast were also far superior in general physical appearance.

Commenting on these results, the authors say that the bread used as a standard was by no means a poor quality bread but on the contrary was somewhat better than the average as the liquid used in its preparation was one-half milk, which is absent from some products. About ten per cent of the protein of this bread was milk protein, while about one-fifth of the protein of the extra yeast bread was yeast protein, the latter also of course containing milk, to make a total of about 30 per cent of non-wheat protein.

Patent wheat flours and breads made from them without suitable addition are known to be deficient in water-soluble vitamine and in protein. The use of milk to the extent of one-half the liquid required or sufficient to replace 10 per cent of the wheat protein by milk protein did not lead to significant gains in weight, in spite of the higher quality of the proteins of milk. That the milk addition should furnish sufficient water-soluble vitamine would not be expected from the relatively low vitamine content of milk as indicated by the work of Osborne and Mendel, who found even 15 cc. of fresh unpasteurized summer milk inferior to 0.2 gram of dried yeast in this respect.

The conclusion is reached, therefore, that "flour containing 5 per cent of yeast powder makes a palatable bread much more nutritious than ordinary bread. Yeast is thus a nutrient constituent of bread, and any increase in its amount up to quantities far in excess of those ordinarily used will improve the food value of the product."

THE DUST OF THE UPPER AIR

Two distinct shells of air compose the atmosphere. The plane of contact between them is approximately 7 miles above sea level, varying slightly with latitude and with the season. The upper shell has been explored to a height of about 20 miles, but extends many miles beyond. So far as known its movements are tidal rather than convectional. Its composition differs slightly from that of the convectional region also. If water vapor exists, the proportion is too minute to form cloud matter. Argon disappears at a height of 40 miles. Carbon dioxide is absent. Above 70 miles hydrogen, helium in minute proportions, and dust constitute practically all there is to the upper air. The diffusion of matter within the stratosphere follows the ordinary laws which govern such movements. Electrical disturbances of Hertzian-wave character are frequent in the upper air and these undoubtedly aid in the diffusion of its dust content, which apparently is highly ionized.

The lower shell of air is the convectional region. The laws of diffusion apply to its content, but convection is the chief factor in the mixture of its constituents. Aside from its lateral movements, the winds, there are also general vertical movements; air is both going up and coming down. The general movements of the air, rather than the laws of diffusion, govern the movement of its dust content.

Coarser particles picked up from the ground fall very quickly. Small particles, especially those of less than 1 micron, fall so slowly that, in many instances, the rate of fall is not measurable; indeed, highly ionized dust particles apparently do not fall at all. If they are brought to the ground it is because they become nuclei of condensation, and not because of their own gravity. Even then, as soon as freed from their load of water, they escape into the air again. In other words the extremely fine dust particles behave much as does molecular matter. Especially is this the case when they are ionized—and possibly their ionization is constant.

The rate of fall of larger particles has been measured. Investigations carried on under the direction of the Transvaal Bureau of Mines show that particles 1 micron in dimension require about five hours to fall six feet. W. J. Humphreys finds that, at cloud height, particles 1.85 microns in dimension fall at the rate of 1 centimeter per 25 seconds, or a little more than 1 inch per minute.

In the region of convection, dust particles are nuclei of condensation. They are essential in the formation of fog and cloud substances. Rain and snow not only bring them to the ground, but also sweep the air free from floating matter of every sort. A snowstorm will rid the air of about everything except the blue haze. The air is never wholly free from dust, however; the cleanest free air carries from 10,000 to 20,000 dust particles per cubic inch.

The foregoing survey of the floating dust of the air is necessary to an understanding of its effects on certain irregularities in the temperature of the air.

Floating dust is mainly the product of volcanic energy. Most volcanic eruptions are steam explosions—that is, the escape of steam and probably other gases, under a pressure that must be reckoned in tons rather than in pounds per square inch. The gases, hydrogen, helium, and sulphur dioxide, along with a generous proportion of water, are a part of the rock which becomes volcanic ejecta. They are occluded within the magma which becomes lava. When the pressure is released the expansive force of the steam and gases blasts the lava into dust and shoots the dust twenty miles or more into the air.

The character of the dust bears evidence of the manner in which it is formed. Dust belched from Krakatoa was caught on slides at Los Angeles a year or more after the eruption. Petrologically the particles were identical with furnace slag. Physically most of them were bubbles of microscopic dimensions. Meteorologically, *en masse*, they formed a screen which intercepted so much of the sun's heat that for about two years the temperature of the air was materially lowered.

The statistics from many Weather Bureau stations report temperature means materially below normals for 1884-1885.

The effect of a dust screen on temperature was pointed out by Benjamin Franklin.

In presenting humanity with values that have a very practical application, Humphreys has gone a step farther than Franklin. He has shown that for every unit of the sun's heat coming to the earth but intercepted by the dust screen, thirty times as much heat is radiated by the earth into space.

One may safely conclude that the effects of a prolonged dust screen on life are profound.—Abstract from article by Jacques W. Redway in *Biology* for April, 1921.

SELECTIVITY OF PAINT AND WINDOW IN PHOTOMETRIC SPHERE

WRITING in the *Electrical World* of Feb. 12, 1921, F. E. Cady describes experiments for the measurement of the error introduced into a photometric determination of the average candlepower of a tungsten-filament vacuum lamp, operating at normal efficiency, when using a comparison lamp tinted so as to match a kerosene flame in color. The error was found to be between 4.5 and 5 per cent when the selectivity of the paint and window of the sphere was such as to introduce a color difference corresponding to a temperature difference of 400 deg. cent. in the vacuum lamp. It is considered that errors of the same order of magnitude may be introduced in the measurement of a gas-filled lamp by means of a vacuum type comparison lamp.

Science and National Progress

Edited by a Committee of the National Research Council

Dr. Vernon Kellogg, Chairman, Dr. R. M. Yerkes, H. E. Howe

BALLOONS, HELIUM GAS, AND THE AGE OF THE EARTH

By Homer P. Little,

Secretary, Division of Geology and Geography National Research Council, Washington, D. C.

The National Research Council is a cooperative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

PHYSICIANS are attempting to cure cancer and goiter, among other diseases, by radium treatment; balloons are being filled with a gas which will not catch fire from an incendiary bomb; physicists, who a few years ago grudgingly allowed the geologist one hundred million years since the earth became solid at the surface, will now as willingly grant him a billion. At the root of all this is uranium, which is the parent of radium and, in part, of helium.

As everyone with even small chemical training knows, hydrogen gas mixed with air is explosively combustible. Yet, until recently, the balloon of the aeronaut, the Zeppelin of the German, and the dirigible of commerce, were most commonly inflated with this gas and subject to the accompanying dangers. A single lightning flash or an incendiary bullet and their careers were over. Helium gas, however, is exceedingly inert, *i.e.*, it tends to remain just helium gas, unchanged under the most varying conditions to which it can be subjected. In this it is much like the heavier nitrogen gas which makes up almost 80 per cent of the air we breathe, but which man has only recently been able to take directly from the air and force to combine with other substances to form nitrogenous compounds for fertilizers. In 1914 a British scientist conceived the idea of using helium in place of hydrogen for inflating balloons. Since helium gas has 93 per cent the buoyancy of hydrogen this was a perfectly practicable idea, but it was a case of first find the gas. Indeed, after a careful search of England and Canada, the project had to be abandoned. The Italians made similar attempts and failed. When the United States entered the war, the Bureau of Mines was assigned the problem and the outcome was another triumph for the men of science of this country for "at the time the armistice was signed, November 11, 1918, the first shipment . . . of 147,000 cubic feet of 93 per cent helium . . . was on the dock awaiting transportation to Europe."[1]

The Director of the United States Geological Survey once defined "pure science," as "not-yet-applied science," implying that there is not the radical difference between the two which the layman supposes. The history of helium is one of the continually accumulating body of facts which illustrate this. Helium was first discovered in the atmosphere of the sun during the study of an eclipse. This was in 1868. Almost 30 years later, in 1895, it was discovered in the earth, first in certain minerals and a few months later in the atmosphere. Careful investigation has since shown it to be present in small amounts in many minerals and rocks, in some mine gases, in the gases of many mineral springs, and in some natural gas. Most important of all, from the standpoint of its commercial utilization, was the discovery about 1905 that the natural gas of Kansas contains helium. To be sure the largest per cent found in any Kansas gas was 2.13 per cent, but when it is remembered that these wells yield millions of cubic feet of gas a day, a natural gas containing even 1 per cent of helium becomes a very valuable source of supply. The importance of this discovery is still more evident in the light of a statement made in 1912 by a foreign authority without consideration of the helium bearing natural gas of the United States, that certain mineral springs producing 1,200 cubic feet of gas a year from their waters were the most prolific source of the element then known.

Investigation has shown that "while most of the natural gas produced in the eastern and central parts of the United States contains at least a trace of helium, gas containing more than 0.5 per cent is known to occur only in two areas, one in northern Texas and the other in southern Kansas and northern Oklahoma." At present 0.5 per cent is about the lowest content consistent with reasonable cost of production. With at least this amount, if the gas is recovered in large-scale plants, the cost should not be over $60 to $80 per thousand cubic feet, with the prospect of appreciable further reduction through a promising new process already in operation.

Theoretically, the isolation of helium gas is simple. It is much like obtaining by fractional distillation from crude petroleum the successive products gasoline, kerosene, and heavy oils. The difference is that while in petroleum the *most desired* products are given off first, in the case of natural gas the *least desired* materials are given off first. In the first case the process consists in driving the required gases out by heating, leaving a less valuable liquid or solid residue; in the second, of driving the less valuable gases out by cooling, leaving a more valuable gaseous residue. Since the three most common gases composing the helium-bearing natural gas—exclusive of the helium gas itself—become liquid only at the low temperatures of 93°, 165°, and 195° cent. below zero, it is evident that the matter of their elimination by cooling is not so simple as might seem at first thought. This is particularly true because of the fact that the perverse helium-bearing gas is always of the type which carries unusually large amounts of the associated gas which has the lowest point of liquefaction, namely, nitrogen. Helium gas itself becomes liquid only at about 268° cent. below zero—the lowest temperature, by the way, ever reached by man. This extreme temperature, however, is not required to separate the helium gas; all that is necessary is to bring the temperature of the mixture below that of the most difficultly liquefied of the associated gases, when a helium rich mixture of gaseous residue will be obtained. As may be seen from the figures above, this will be at about 200° cent. below zero.

There are three processes by which the required cooling is accomplished, two of proven worth and a third which is theoretically superior to the others. All make use of the familiar fact that expanding air is cooled. The boy who lets the air from a bicycle tire or the man who deflates his automobile tube, know that the escaping air feels cool. This is because of its expansion under decreased pressure. The same principle underlies the manufacture of artificial ice. If, in addition, the air had been considerably chilled by being subjected to an intense cooling action before its escape, its

[1] G. Sherburne Rogers. Helium-Bearing Natural Gas. Professional Paper 121, U. S. Geological Survey, 1921.

self-cooling would have brought it to a still lower temperature. It is evident that in dealing with natural gas, each successive gas liquefied becomes a cooling agent for lowering the temperature of the remaining gases before they are allowed to cool themselves by expansion. The effectiveness of the process is still further increased if the gases are under very great pressure before being allowed to escape. So far, the process using these principles most baldly has been most effective; in the other processes a portion of the compressed and cooled gas is forced through an expansion engine and made to do work instead of merely expanding through a fixed throttle. This does away with the requirement of high pressure machinery and should result eventually in the production of helium gas more cheaply.[2] At any rate, the United States was able between the time of entering the war and the signing of the armistice to develop a successful helium gas industry. Previous scientific research had already indicated a possible source of material; the investigations of the Bureau of Mines, assistance from the National Research Council, and the coöperation of certain English companies who specialized in gas liquefaction furnished the technological skill; the Geological Survey through its investigators showed the possible extension of the productive areas; many gas companies and individuals also contributed to the desired end. It now seems probable that helium gas can be produced at a sufficiently low cost to allow of its common use for the inflation of commercial air-craft.

The length of time that the supply of helium gas will be available for commercial purposes is closely joined with a national conservation policy, for perhaps in no instance has this country been more profligate of its resources than in the case of its natural gas. Yet in connection with this resource is the only large commercial supply of helium gas known. Since, under even the most careful control, the life of a gas well is comparatively short, the value of preventing unnecessary loss is evident. As a rough approximation of the resources, Dr. G. S. Rogers estimated in September, 1918, that if every field producing at least 3 million cubic feet a day of a natural gas containing 0.35 per cent or more of helium is taken into account, a weekly production of about 6 million cubic feet of helium (not counting losses in extraction) could be maintained for two and one-half to three years. If production is held below its maximum, the life of a given supply is of course correspondingly increased. The helium of natural gas may be primordial or derived from uranium as described below.

We have referred to the changed attitude of the physicist toward the age of the earth. Strange as it may seem, this question ties in with the origin of helium. It does this through radioactivity, the property possessed by some substances of spontaneously giving off invisible rays capable, among other peculiarities, of affecting photographic plates, and of penetrating objects opaque to ordinary light. This phenomenon of radioactivity was discovered in 1896 and it was interest in its further investigation which led Madame Curie to the discovery of radium. Later patient and skilful research seems to have established several striking facts. It appears that various minerals carry the rare element uranium; this disintegrates into radium after several intermediate steps, and the radium itself eventually disintegrates into polonium—familiar to many as another rare element discovered by Madame Curie and named after her native Poland. Polonium probably disintegrates into lead, and this completes the series so far as our present knowledge goes. As these substances disintegrate they give off three kinds of "rays," one or all of which may be given off by a single substance, depending on its individual characteristics. The fact of peculiar interest to us is that *the most important rays given off have been shown to be atoms of helium.* This discovery proved for the first time the derivation of one element from another.

Since each radioactive substance breaks down at a definite and characteristic rate the ratio of helium to uranium should be greater in ancient minerals than in recent ones, and so furnishes a means for measuring geologic time. The previous method in vogue among physicists for estimating the age of the earth was to assume a certain reasonable temperature for the earth at the time of its solidification and then to calculate the length of time required for it to cool sufficiently to have the present surface temperature gradient. This method was based upon the *hypothesis* that the earth was formerly a highly heated molten body and the *fact* that it shows today a more or less constant increase in temperature as its crust is penetrated—the thermal gradient. Assuming any original temperature, it is possible to calculate how long it would take the earth to cool to the present gradient, provided there had been no later accession of heat. Several variable factors besides the original temperature enter into the problem; the best results of this method gave 20-100 million years as the age of the earth. The fact that the degeneration of the radioactive elements produces an enormous amount of heat destroyed the validity of the method on the one hand; on the other, it offered as a substitute what has been called "the most elegant method of measuring geologic time." This is because the disintegration of uranium and consequent production of helium proceed at fixed rates. From both calculation and experiment it is found that one gram of uranium will produce helium at the rate of one cubic centimeter in 9,600,000 years. The ratio between the amount of uranium in a mineral and the amount of helium present therefore allow us to calculate the age of the mineral. The amount of uranium originally present compared to that left does not enter into the problem unless extreme lengths of time are under consideration because of the fact that it is calculated to take 5,400 million years for one-half a given volume of uranium to disintegrate.

It is perfectly true that much of the helium generated may escape. The assumption is, however, that in some minerals comparatively little escapes; zircon, particularly, seems to be an effective retainer. This mineral shows very effectively the increasing ratio of helium to uranium as consecutively older rocks are examined. Recent or Pleistocene specimens from Vesuvius show an apparent age of .1 million years; Miocene specimens from the Auvergne, France, of 6.3 million. The Devonian of Norway furnishes specimens 54 million years in age, and the Upper Cambrian of Colorado specimens of 141 million years; the Archean of Ceylon, of the diamond-bearing rocks of South Africa, and of certain rocks of Ontario furnish specimens aged 286, 321 and 715 million years, respectively.

Attempts to calculate age from the ratio of uranimum to lead are of even greater significance for the reason that lead is not so likely to have been dissipated as helium. The resultant values from these calculations indicate that the Devonian rocks are 370 million years old; the rocks next younger than the Cambrian 430 million years; and the younger and older Archean rocks respectively 1,000 and 1,400 million years.

The dependability of these methods has been questioned and they are of course at best only approximations. Yet they are wonderfully suggestive as a possible means of throwing light on one of the profound questions which has interested man—the age of his dwelling place, the earth. One enthusiast in this problem says "Radioactive minerals, for the geologist, are clocks wound up at the time of their origin. After a few years of preliminary work, we are now confident that the means of reading these time-keepers is in our possession. Not only can we read them, but if they have been tampered with and are recording time incorrectly, we can, in most cases, detect the error and so safeguard ourselves against false conclusions."[3]

[2] For a résumé of the history of liquefaction of gases, together with description of the Linde and Claude processes which were used, reference may be made to Vol. III, Thorpe's Dictionary of Applied Chemistry, pp. 325-332.

[3] Arthur Holmes, "The Age of the Earth." Harpers. Reviews in an understandable way the various methods which have been employed in estimating the age of the earth.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

TESTS OF CENTRIFUGALLY CAST STEEL

THE production of metal castings by the centrifugal process may be said to have passed beyond the experimental stage; at least, in the case of certain non-ferrous metals and cast iron shapes. However, very little appears to have been published concerning centrifugally cast steel. Opportunity was given to the Bureau of Standards to examine in detail the physical and chemical characteristics of six centrifugal castings made by the Millspaugh process.

The results are interesting since they show what may be expected from such metal as compared with the product of more usual manufacturing processes. The advantages to be expected from centrifugally cast steel are physical soundness and freedom from chemical segregation and thus the elimination of waste metal to be discarded, which last is always a very important factor in other casting processes. For certain shapes forging and boring operations may be eliminated.

The investigation shows that highly satisfactory castings which are physically sound and free from serious segregation may be produced by the centrifugal method. It is shown that the properties of these castings can be greatly improved by subsequent heat treatment, the resulting metal being in a condition to compare favorably with metal that has been forged.

Technologic Paper No. 192 of the Bureau of Standards has just been issued dealing with the above subject and may be secured from the Superintendent of Documents, Washington, D. C., at 10 cents per copy.

TEMPERING OF HARDENED STEELS

A VERY thorough investigation is under way in the metallurgical division dealing with the microchanges which occur during the tempering of hardened steels. Some idea of the work involved in this investigation may be gained when it is remembered that it is necessary to take hardness measurements and make microscopic examination of all the specimens of each type of steel for each tempering treatment. Over 800 specimens are involved in the investigation and the time necessary for the mere polishing for examination is very considerable.

CORROSION OF SOFT METALS

THE results of the investigation of corrosion of soft metals have been assembled and work on a publication will soon be started. The investigation was conducted for the purpose of determining to what extent intercrystalline embrittlement occurs in the soft metals—zinc, aluminum, and tin, as a result of prolonged corrosion. The behavior of lead has previously been studied. An additional study of the last-named metal to show the accelerated influence of applied stress in causing embrittlement by corrosion was also made.

THERMAL STRESSES IN STEEL CAR WHEELS

THE investigation of stresses in cast iron and rolled steel railroad wheels has now been in progress for some time and has already been mentioned in this publication. With the aid of the results obtained from tensile tests on material taken from the wheels and thermal expansion data obtained on similar materials, computations have been made of the stresses set up by heating the tread of various steel wheels. It was found that the stresses on the outside of the wheel were in compression near the tread and in tension near the hub, the maximum value being in each case greater than the proportional limit of the material. This distribution is similar to that previously found in the single plate cast iron wheel. In order to analyze further the stress distribution in the wheels, some of them are being prepared in such a way that stress measurements can be taken on the back and also in a circumferential as well as a radial direction.

SPECTROSCOPIC ANALYSIS OF GOLD

SIXTEEN samples of standard alloys of gold were prepared for the purpose of standardizing a spectral method to be used in determining the quantities of impurities in this metal. The partial spectra of iron, copper, silver, and lead shown by these standard samples have been carefully studied and the method of making quantitative estimates of these metals from their spectra alone has been established for the range 1 per cent down to 0.0001 per cent. This investigation was undertaken for the United States Mint where the results will be used in making analyses of proof gold.

INVESTIGATION OF REINFORCED CONCRETE AND TILE FLOORS

DURING the past month work has been pushed on the preparation of a publication which will give the results of the extensive test of a reinforced concrete and clay tile floor slab which was carried out by the Bureau at Waynesburg, Ohio, and which has been mentioned before in this magazine.

This paper, which will probably be issued as one of the Technologic series, will contain information which should be of much interest and value in connection with the now important problem of reducing the cost of building construction. It is not possible to state just when this paper will be ready for distribution, but the work of collecting the data is now practically completed.

COLORLESS WATERPROOFING FOR BUILDING STONE

A PRELIMINARY report is being prepared based on results obtained in the investigation of colorless waterproofing materials for building stones, some of this work having previously been mentioned.

This report will describe the nature of the materials, the appearance of the treated stone, the depth of penetration, and the effectiveness of various preparations in preventing water absorption during a period of 6 months' exposure to the weather.

THE INVESTIGATION OF AUTOMOBILE BRAKE LININGS

A CONFERENCE recently held at the Bureau of Standards between manufacturers of automobile brake linings and representatives of the various government departments interested in the purchase of this class of material was mentioned in the last number of the SCIENTIFIC AMERICAN MONTHLY. This investigation has steadily proceeded during the past month and some important facts have been brought to light.

When one considers that the safety of automobile travel depends very largely upon the ability of the brakes to hold the car under all conditions and stop it within the shortest possible time, the importance of this work may be appreciated. The Bureau has proved beyond doubt that material to be at all suitable for this purpose should have a coefficient of friction very much higher and more uniform than is necessary for ordinary work. Extremely severe conditions of load and temperature are encountered every day and the material must be capable of standing up under them.

It appears from the investigation of many commercial brake

linings already completed that the coefficient of friction, that is, the holding power of the brakes, with some of these lining materials, may fall below one-third of its normal value the first time the brakes become hot. On cooling again, the normal condition is restored. Used linings do not show this reduction in friction to such an extent. Some lining materials will wear 10 times as long as others in the same service but the causes of such differences have not been entirely explained.

PHOTOGRAPHIC INVESTIGATION

DURING the past month quantitative measurements of sensitometer speeds, filter factors, etc., have been made with specially treated emulsions and some interesting and important information on the relative values of the different methods of treatment (washing, ammoniating, photosensitizing) as regards spectral sensitivity, total speed, fog, and keeping qualities, have been obtained. The results are now being collected and it is hoped to publish them as a scientific paper entitled "Studies in Methods of Color Sensitizing Photographic Plates."

CIRCULAR ON TELEPHONE SERVICE

CIRCULAR 112 of the Bureau of Standards on Telephone Service has just been published and may be obtained from the Superintendent of Documents, Washington, D. C., at 65 cents per copy.

The product which a telephone company sells is service but from an analytical standpoint the service as a whole must be divided into its elementary characteristics which are peculiar to the nature of the service and to the manner in which it is rendered.

The primary object of this circular is to enumerate these elements and to explain how the grade of service is dependent upon each of them. As some knowledge of the manner in which telephone service is rendered is a prerequisite for understanding a discussion of graded telephone service, the secondary object of this circular is to furnish the reader a sufficiently extensive description of modern telephone practice. This description is non-technical in character and so far as operating methods are concerned includes only those methods which are most essential. These are, however, so numerous that the greater part of the circular is given to their consideration.

Service in general is considered in the introductory section while description of the telephone plant and its operation are given in sections which respectively consider developments of the telephone art, equipment of manual systems, equipment of automatic systems, outside line construction, and telephone traffic. These are followed by the section on the principal elements of telephone service.

Attention is especially directed to the section entitled "Principal Elements of Telephone Service." Here are considered those service characteristics which are outlined in the determination of the grade of service and thus there is furnished a basis for future work along the lines of service standards. The elements are considered in groups each having common service relations and the most important factors involved in each case are enumerated and their relations to the grade of service are explained.

A section on the subject of public relations has been included to cover those phases of telephone service which receive attention by regulatory commissions both Federal and State. Plant extensions, abandonment of service, physical connections, accounting, valuation, rates, rate schedules, contracts, collections, and discrimination have been considered. A conclusion is drawn regarding the subject of service standards. The rapid and extensive development of the telephone industry is indicated by statistics given in the form of an appendix.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

By H. E. Howe, Member of American Chemical Society

IMPROVEMENTS IN NICKEL SOLUTIONS

DR. WILLIAM BLUM presented a paper before the Electro-Chemical Society at its recent meeting in which he described the use of fluorides in solutions for nickel deposition. The results which have been secured have an important bearing upon the composition of nickel solutions where an adherent deposit which shows resistance to abrasion is desired. The work is the outcome of an investigation which has led to a process for the electrolytic reproduction of engraved printing plates used by the Bureau of Printing and Engraving. It was necessary to produce surface nickel coatings of extreme hardness free from brittleness and without a tendency to curl.

In Dr. Blum's paper he discussed the general principles and the chemistry involved including methods for the control of the solution involving analysis, testing for acidity and the application of hydrogen ion measurements in this connection. There is also a discussion of the anodes used and the important bearing of the conductivity of the plating solutions. The following are the conclusions reached by Dr. Blum:

"When nickel or sodium fluoride is added to nickel baths containing boric acid, fluoborates more complex than those corresponding to the formula HBF_4 are probably produced. The fluorine content of such solutions can be determined approximately by titration with ferric chloride.

"The effect of boric acid and hydrofluoric acid upon the hydrogen ion concentration and neutralization curve of nickel sulphate solutions has been studied, and their function in plating solutions has been suggested.

"Nickel deposits produced in solutions containing fluorides have a finer structure and a higher tensile strength than those produced in corresponding chloride solutions. When prepared with anodes containing about 97 per cent of nickel, there is slightly more iron and copper in the fluoride deposits than in the chloride.

"The anode corrosion in solutions containing fluorides is good and the solutions produce less sludge than do corresponding chloride solutions. Attempts to use electrolytic anodes in such solutions at reasonably high current densities have not yet been successful, but the results with hot-rolled anodes are promising.

"The use of fluorides in nickel solutions for electrotyping will probably increase the wearing quality of the printing surface. In electroplating good deposits can be secured in the presence of fluorides at somewhat higher current densities than are ordinarily employed, and these deposits, while slightly harder to buff, show greater resistance to abrasion."

THE ESTIMATION OF COMBUSTIBLE MATERIALS IN AIR

E. BECKMANN has reported results of an investigation upon the subject of fire damp in a paper entitled "Process for Testing the Content of Combustible Materials in Air" in a German publication which has but recently become available. It is abstracted in *Science Abstracts* No. 278. The various kinds of coal and the occurrence of methane therein are first discussed. The author found that only 3 per cent of methane is necessary in air carrying much coal dust to give rise to an explosion. Previously 6 per cent of methane has been regarded as without danger. Beckmann attempted a solution of the problem determining the percentage of methane or

fire damp in air by chemical means and sought a suitable method of oxidizing methane into carbon dioxide and water in a way to adapt it to analytical purposes. Davy's lamp makes it possible to recognize as little as one quarter of a per cent of fire damp and the author discusses various other forms of testing apparatus.

The effort to devise chemical methods was unsuccessful and Beckmann then turned to a method of testing the danger of a methane-air mixture by its explosibility. The test by this method occupies about three minutes and the original paper describes a proposed apparatus and experiments which have been conducted with it including tables of results. Work has been done with an excess of oxygen and with a deficiency of oxygen. In the latter case carbon monoxide makes its appearance.

CONSTANT TEMPERATURE BATHS

IN discussing some physical properties of hydrocarbons containing two or three carbon atoms Maass and Wright in the May number of the *Journal of the American Chemical Society* include a description of constant temperature baths used by them in their experiments. As many others may be working at low temperatures the following is quoted from their paper:

"Temperature baths to be constant to 0.1 degree at any particular temperature were required throughout the range of temperature from 0° to -200°. From 0° to -78° the bath consisted of ether, contained in a Dewar flask stirred by a current of dry air, the temperature being hand-regulated by the addition of small amounts of solid carbon dioxide. It was found to be advantageous to use instead of pure ether an alcohol-ether solution containing 20 per cent of alcohol. Water is insoluble in pure ether at low temperatures, so that moisture from the atmosphere condensing in the ether-bath rendered the latter opaque. Alcohol-ether solution, on the other hand, dissolves considerable quantities of water even at -80° without becoming viscous as alcohol does at this temperature, so that this bath remains transparent throughout the experiment.

"From -78° to -160° the bath consisted of the first distillate from petroleum ether condensed by use of a salt-ice mixture as cooling agent. The temperature of this bath was regulated by the addition of liquid air, as explained diagrammatically in a previous paper. Below -160° the petroleum ether became very viscous and generally unsatisfactory.

"From -160° to liquid-air temperature the bath consisted of liquid propylene cooled by liquid air. The propylene liquid is contained in a large test-tube held in a vertical position by means of a stiff wire, which is placed in an unsilvered Dewar flask containing a quantity of liquid air. It is held in position so that it may be raised or lowered at will. The propylene is cooled by contact with the liquid air and by intermittent raising and lowering of the Dewar flask the temperatures, as read by a thermometer, can be maintained at any temperature between -160° and the boiling point of liquid air to within 0.1° provided the test-tube be of thick glass and the propylene be subjected to vigorous stirring by means of a stiff steel wire. Propylene used for such a bath can be conveniently stored in a gasometer and can be used over and over again if care is taken to dry it before each condensation.

"From the boiling point of liquid air to -205° the bath consisted of liquid air in a test-tube surrounded by liquid air which could be cooled by boiling under various degrees of reduced pressure. For temperatures below -200° the air bath must necessarily be closed off from the atmosphere on account of the heat changes caused by the rapid condensation of the air of the room in its vicinity."

COLORS FOR STENCILING AND STAMPING

THE following abstract on this subject is from the *Farben Zeitung*, 1921, p. 1508, by way of the *Color Trade Journal*:

"Colors used for marking packages, boxes and such like articles, also for the marking of samples and goods of various descriptions have become quite an important industry. Since their preparation does not present any particular difficulties, it is possible for small establishments to engage in their manufacture without very great installation or equipment. Most of the colors used for stamping inks, particularly where the rubber stamp method is employed, are made principally from coal-tar dyestuffs dissolved in glycerin. The coal-tar coloring matter is placed in a porcelain or enamel dish, mixed with concentrated glycerin and heated with constant stirring for a considerable time at about 200° fahr. In this preparation care should be taken not to use any more glycerin than is absolutely necessary. In order to test out the character and consistency of the ink it should be soaked into a piece of cloth and then the stamping test made with a rubber stamp. It is not possible to give a general formula for preparation of these inks as the proportions of glycerin will vary with the character of the dyestuffs used, and it is only by testing out in the manner described that a suitable proportion of the ingredients can be discovered in making up considerable quantities of such material. The glass or enamel vessel may be filled three-quarters full with glycerin, and then a water soluble aniline dyestuff is added until the mass becomes quite thick in consistency. The mixing vessel is then placed on a sand bath and heated until the boiling point is almost reached, being careful to keep the material constantly stirred. In this manner violet, green, blue, brown, eosine and coralline will be found to dissolve even in lukewarm while fuchsine requires several minutes' boiling. The resulting syrupy mass is then spread thinly on flannel or leather. Since the glycerin is practically a non-drying substance a well prepared stamping pad may be used for a year or more. According to another process a mixture is made containing 20 parts of acetic acid, 10 parts of alcohol and 70 parts of glycerin, and in this the aniline color is dissolved as before; only in the case of eosine is it necessary to substitute the acetic acid with the same quantity of water. The violet ink can be made by dissolving one part of crystalline Methyl Violet R in 20 parts of alcohol and then adding to this solution 30 parts of glycerin. In order to produce an oil free black stamping ink, 100 parts of tannic black are dissolved in a mixture of 100 parts of water and 200 parts of glycerin, and the mixture heated with proper stirring until completely dissolved. All of the coal-tar dyestuff inks can be washed out with either alcohol or caustic soda, and in order to prepare a so-called washing fast ink it is necessary to use one prepared with silver nitrate. In order to wash out this latter it would be necessary to use a solution of potassium cyanide. Washing fast black ink can be prepared by using 20 parts of copper sulfate and 30 parts of aniline hydrochloride. These are finely divided and mixed together, and then 10 parts of dextrin is added. The mixture is then rubbed up with 5 parts of glycerin and 5 parts of water until a thick, uniform mass is obtained. Another suitable black ink is obtained by using the following ingredients: 10 parts of water, 10 parts of acetic acid, 10 parts of alcohol, 70 parts of glycerin and 4 parts of Nigrosine. Blue or violet ink can be made in the same manner by using in place of the Nigrosine, 8 parts of Aniline Blue or 8 parts of Methyl Violet. Sometimes glue or gelatin are added to the glycerin and dyestuff, in which case the glue is first finely divided and then steeped in cold water before being boiled up with the glycerin and the dyestuff."

WATERPROOFING AND MILDEWPROOFING CLOTH

THE Department of Agriculture in *Farmers' Bulletin* No. 1157 discusses waterproof and mildewproof cotton duck and gives formulæ which are designed solely for waterproofing and mildewproofing treatments. Of the several existing types of waterproofing processes five general classifications can be made: (1) Those in which the water resistance is due to insoluble metallic soap; (2) those which depend upon wax such as paraffin; (3) those which use such bituminous materials as asphaltum or tar; (4) those employing drying oils

such as linseed oil and, lastly, various combinations of these other types.

Following the investigations, these four formulæ have been advocated as meeting the requirements of those using canvas for outdoor purposes:

FORMULA 1

	Pounds
Amorphous mineral wax or crude petrolatum	7½
Yellow beeswax	1
Refined Bermudez Lake asphalt	1½

Solvent: 3 gallons gasoline and 2 gallons kerosene.

FORMULA 2

	Pounds
Petroleum asphalt (medium hard) or Bermudez asphalt	6
Neutral or extracted wool grease	2½
Lead oleate, technical	1½

Solvent: 3 gallons gasoline and 2 gallons kerosene.

FORMULA 3

	Pounds
Amorphous mineral wax or crude petrolatum	8½
Yellow beeswax	1½

Solvent: 3 gallons gasoline and 2 gallons kerosene.

FORMULA 4

	Pounds
Amorphous mineral wax or crude petrolatum	6½
Yellow beeswax	1½
Lead oleate, technical	2

Solvent: 3 gallons gasoline and 2 gallons kerosene.

Applications of mixture made by formulas 1 and 2 give the canvas a dark brownish color, while those made according to formulas 3 and 4 give it a light buff to khaki color. The first two are preferable for all purposes where a dark color is not objectionable.

The amphorous wax referred to is very similar to petrolatum and is a by-product in refining chilled cylinder-oil stocks. The Bulletin discusses certain substitutions that can be made with propriety and indicates where the more unusual materials named can be obtained. Of course in all instances precautions must be taken during mixing to avoid fire.

In applying these mixtures a brush may be used or where large surfaces are involved a spray pump operated at a pressure of at least fifty pounds can be used to advantage notwithstanding some loss of material which accompanies this method. The experience has been that one coat applied to one side of the canvas is usually sufficient. This will increase the weight of the material from 3½ to 4½ ounces per square yard and ten pounds of material with five gallons of the solvent will ordinarily treat about forty square yards of canvas.

INK CONSIDERED HISTORICALLY

THE *American Dyestuffs Reporter* gives the following interesting items with reference to the history of ink:

"Ink, considered from a historical standpoint, is extremely interesting, samples of Egyptian writing, which are still plainly legible, having been produced as early at 2500 B.C., while it is generally conceded that other specimens of papyri date back to at least 3500 B.C.

"The ink used by the earliest writers undoubtedly consisted of a carbon base prepared either by burning wood or animal matter, after which same was ground to a fine powder and properly combined with oils and gums, and probably oftentimes thinned with water to the proper consistency for writing.

"'India ink' was invented by the Chinese about 1200 B.C. and was prepared by mixing a very fine soot with a gelatine prepared from asses' skin.

"The greater number of documents which have come down to us from the medieval times were written with 'India ink.' Owing to the permanent character of writings made with 'India ink' there is still a very strong tendency to use this type of ink in many modern documents. While 'India ink' has no tendency to disintegrate with time, it can be obliterated if treated with water.

"Tannin-iron inks were introduced into Europe from Arabia during the early part of the twelfth century.

WRITING MATERIALS

"Papyrus, vellum and parchment were the earliest forms of material upon which ink writing was practised.

"Papyrus was largely used by the early Egyptians and many perfectly preserved specimens have been found in the pyramids of the Pharaohs. Papyrus was prepared from a form of reed which grew luxuriantly on the banks of the Nile.

"Vellum was prepared by the proper treatment of the skin of calves, while parchment was prepared from the skin of the sheep.

"The materials used for applying the ink to the paper consisted at first of reeds and brushes, and later the stylus pen. During the sixth century the quill pen came into existence and its use was continued for centuries.

"Steel pens first came into regular use in 1803, and ever since that time the makers of the steel pen have been endeavoring to duplicate the desirable qualities of the quill pen."

ASPHALT ANALYSIS

H. J. ROSSBACHER, in the June *Chemical Bulletin*, discusses the interpretation of asphalt analyses. Asphalt analysis consists principally in the application of a number of empirical tests designed for the purpose of measuring the consistency of the material and for determining its source as well as the degree of skill that has been exercised in preparing a particular product for its purpose.

The tests applied for consistency and sensibility to temperature are penetration, viscosity, melting point, and the float test. In routine work, penetration is determined at 25 deg. cent. with a load of 100 grams, and a time interval of five seconds. The depth in millimeters to which a weighted needle sinks into the sample under the conditions of time and temperature mentioned, is called penetration. Viscosity is determined with the Engler viscosimeter and for those asphalts which are too soft for the penetration test and yet too viscous for the viscosimeter there has been developed the float test. This value is the time required to melt out a cylinder of the material from a collar screwed into a metal bowl and floated in warm water. By standardizing the temperature of the sample cylinder or plug at the start and the temperature of the water, tests are reproducible within two seconds. The melting point is determined according to the methods described by the American Society for Testing Materials.

Other tests are the determination of ductility which indcates the relative cohesion of the various materials of a given consistency, fixed carbon, the flash point, evaporation loss, and specific gravity. Solubilities are determined with carbon disulphide, carbon tetrachloride and 88 deg. naphtha. The result of the first test gives the bitumen content and the difference in solubility with disulphide and tetrachloride is usually interpreted as an indication of the extent to which the sample has been weathered or perhaps overheated during compounding. Solubility in naphtha serves to indicate the type of material. As the author says, "It is probable that no type of material is made the subject of wider or more unsubstantiated claims than is asphalt. Asphalts consisting as they do of colloidal combinations of organic compounds of unknown composition continue to offer a verdant playground for the imagination of the promoter and salesman. There is a need, therefore, for scientific investigation of the properties of asphaltic materials and the chemist who is called on to pass on the properties of a particular compound for a given purpose should 'maintain an attitude of healthy skepticism.'"

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

By A. Slobod

DIRECT RESEARCH AND DIRECT RESULTS

With the depression of trade prevailing at the moment the tendency is to cut down expenses; but insufficient distinction between expense and expenditure is often falsely called economy, and, according to G. A. Percival, writing in *Beama* for June, 1921, money spent on properly organized research is investment. As Disraeli expressed it: "True economy does not consist in reckless reduction of expenditure." Expenditure in the right direction leads to efficiency, and efficiency is the truest form of economy.

The author first discusses the necessity of research. Cheap living is the key to national prosperity, and this becomes possible with improvements in machinery and manufacturing processes. He then takes the aversion of the average business man to invest his money in research. The word "invest" is used deliberately, as all research, if carried out properly, is investment and not speculation; it is in fact a gilt-edged security. He cites the firms of Brunner Mond in England, the G. E. in America, and Krupp in Germany as organizations which have been built up on research. In fact the largest manufacturing concerns in every country have been developed on the same principle.

The functions of research workers may be classified as pure and applied, or direct and indirect. Pure or direct research can be engaged in only by the largest corporations or by the coöperation of several smaller manufacturers, but the various institutions for carrying on investigations of a purely scientific nature rely, to a large extent, upon the generosity of industrial concerns interested in a similar class of work. Although such research is often apparently tedious and useless, it eventually plays its part and returns a handsome interest.

In the control or routine work the research is largely a question of "looking for trouble." A "soft job" while all goes well, but "there to be kicked" when things go wrong. It is a department recognized by a firm of any standing as of as much importance as the accountants. Every manufacturing operation has several processes, and quite apart from any question of testing incoming and outgoing material, the precision of operations is as vital as the perfect circulation of the blood in a human body. A small change, an error overlooked will creep into the heart and the poison will require time and care to eliminate.

While care in selection of material is of prime importance, in many factories the mistake is often made of confusing process work with material control. They are links in the same chain and of equal importance, but they are distinct. Both these sections, however, are indirect research, inasmuch as the continual accumulation of data, the effects of slight variations in material and methods, are collected and are available for further development. A slight change due to unforeseen circumstances often gives extremely interesting results, which, if carefully followed, may lead to entirely new methods. Such changes must be followed in detail and the effects throughout manufacture studied before being put into operation. Because work of this kind is of a definitely commercial nature it is indirect research, as distinct from absolute research.

After indicating some ways of financing and coöperating the efforts in pure research the author concludes thus: "The object of pure science is to advance knowledge; that of applied science to obtain financial benefit, but the first may prove a greater financial asset, while the latter may develop only much theory on the subject. They are complementary to each other and must be fostered and developed together."

OZONE "PURE-AIRIFIER"

This is a new type of ozonator which effects a saving of fuel in ventilating work. This saving is based upon the difference in temperature between the outside air and the used interior air, which can be recirculated after ozonation with considerable less addition of heat. An assembly of twenty-five units has a capacity of 25,000 cu. ft. of air per minute. A rheostat is used to control the degree of ozonation, and a step-up transformer gives the necessary high voltage.

The construction of the unit consists of a smooth electrode of aluminum which slips into a cylinder of Pyrex glass, the glass acting as the dielectric. The exterior electrode is a sheet of aluminum, expanded to form a number of small points, and then bent into cylindrical form to fit around the glass cylinder. All conducting wires are made of aluminum. The advantage claimed for this type of construction is that the discharge is a continuous static glow discharge, rather than crackling electric spark, thus eliminating the formation of nitrous oxide. The power consumption is low, being 120 watts for the twenty-five unit system running at capacity.—*Heating and Ventilating Magazine*, March, 1921. Through *Sibley Journal of Engineering*.

THE LONGEST SUBMARINE TELEPHONE CABLE

East Prussia has been separated from the German mainland by a wedge-shaped territory assigned to Poland. To obviate international difficulties from overland telegraph and telephone lines, Germany decided to lay a submarine cable, bridging by sea the Polish wedge. This submarine telephone cable to East Prussia is the longest in existence, having a length of 170 kilometers. The cable contains six telephone pairs and three single telegraph wires. Each of the twelve telephone wires is covered with a double layer of annealed iron wire. All conductors are paper insulated. Owing to a depth reaching 110 m. at its greatest point, a double lead sheath, a double spiral of steel wire and finally an outer interlocked steel armoring have been used. Each 1½ miles a water stop has been built into the cable to localize any entrance of water into the cable in case of break. The over-all diameter of the submarine cable is about 2 inches and its weight is 8 pounds per foot. The manufacturers delivered the cable in three lengths (21, 77 and 77 km.). A 1,000-ton freighter with a modern paying out machine mounted on its stern was used and finished the work in two trips of sixteen and thirteen hours' actual laying time.

The required guarantee data for one kilometer of telephone line, alternating current, 800 cycles and 150 deg. cent. were: Effective resistance, 12 ohms; self-inductance, 0.009 henries; mutual capacity, 0.052 mfd.; specific damping, 0.015; insulation resistance, 2,000 megohms.

The author gives a complete account of actual test methods and results obtained by the postal authorities at the final inspection. The telegraph lines operate with Siemen's rapid telegraphs, and vacuum-tube amplifiers are used for the telephone lines.—*Elektrotechnische Zeitschrift*, April 7 and 14, 1921. Abstract, *Electrical World*, June 18, 1921.

CARRIER CURRENT TELEPHONY AND TELEGRAPHY

A very exhaustive paper on this subject appeared in the *Journal of the American Institute of Electrical Engineers*. The authors of this paper are Messrs. E. H. Colpitts and O. B. Blackwell. The final part of the paper will be found in the June issue of the above-mentioned journal; it is accompanied by a bibliography covering the period of 1867-1921.

It is interesting to note some of the conclusions reached by the authors: The carrier telegraph and telephone systems are designed to fit as an integral unit into a comprehensive wire plant, the relay-circuit arrangements providing for automatic repetition between the carrier channels and the connecting circuits, whether the latter be subscribers' loops or an additional section of long-distance circuit. The carrier telegraph circuits are used in the Bell plant, as are the regular composited Morse circuits, to furnish leased-wire service. The requirements for this service are particularly exacting as regards continuity and quality. The carrier telegraph circuits have proved to be very satisfactory in meeting these demands.

Carrier telephone systems—at least in the present state of the art—are economical in a general public service communication system only for use over relatively long distances. Of course, whether carrier systems can be justified in any given case depends upon factors peculiar to that case; in some instances, for example, it may not be physically possible to provide additional wires over a given toll line or cable route, in which case the relatively high apparatus costs may be easily justified. The carrier telegraph system is also essentially a long-distance proposition, although it is sometimes possible to warrant its use for distances somewhat shorter than in the case of telephone systems.

Another paper on the same subject was contributed by Chas. A. Culver to the March, 1921, issue of the *Journal of the Franklin Institute*. It deals primarily with the system of multiplex telephony invented by General Squier. It is defined as that of high-frequency electrical resonance, combined with the use of an integrating translator which delivers to the telephone receiver a varying unidirectional current corresponding to the voice current supplied to the modulating device at the transmitting station. The development of the three-electrode tube with its repeating, amplifying and modulating properties, and more particularly its qualities as a high-frequency alternating current generator, made possible the wide application of the guided-wire system. In the Squier system several such transmitting organizations with suitable frequency intervals are bridged across a physical telegraph or telephone circuit, each organization corresponding to a similarly tuned receiver at the other end. Thus, several and independent conversations are made possible over one pair of wires.

The number depends somewhat upon the electrical constants of the line and also upon certain inherent limitations which are discussed. A frequency difference of at least 20,000 must be allowed between sets. Frequencies up to 500,000 and down to 15,000 may be used, allowing for the elimination of the "beat notes" this would permit of at least six guided-wave two-way conversations in addition to the ordinary line conversation. It is asserted that the number of super-imposed conversations may soon be doubled. The author has designed a new circuit in which the high-frequency oscillation tube also serves as a detector and is used both for transmission and reception; furthermore no energy is delivered to the line except when one speaks into the microphone.

It is possible under certain conditions to operate high-frequency super-channels over adjacent parallel circuits, say, on the same pole, without cross talk. Copper, copper-clad iron and aluminum wire will serve for carrier circuits, but not galvanized iron. It is an important fact that high-tension power transmission lines may be utilized by electrostatically coupling the high-frequency equipment to the power line through suitable high-tension condensers, or by its direct connection to a wire a few hundred feet long supported parallel and close to the power wires. There is no interference from power circuits. There is a possibility of interference from radio stations, but this may be obviated by avoiding the neighborhood of their frequencies. Statics are less serious than in ordinary radiotelephony. The advantages of the guided wave systems are summarized as better voice reproduction, greater secrecy possibilty of maintaining communication even when wires are broken, flexibility, possibility of communication with moving trains and finally, in its main application to the extension of the traffic capacity of the existing lines.

A FUSE IN UNEXPLOSIVE OIL

THIS paper describes in detail a type of fuse which can be used on circuits up to 45,000 volts, with maximum rupturing capacity of 13,500 kva., with sectional drawings and photographs. As this piece of apparatus is very compact and small for its capacity, it represents a distinct advance over the older types.

It consists essentially of a porcelain oil-tight grip container, held in the usual form of contacts, the oil level being three-quarters of the way up; the fuse wire itself is held between two screws, above the level of the oil; the lower screw being movable and contained in, but insulated from, a metallic cylinder, divided into two chambers round the base of which are holes below the level of the oil connecting with the porcelain container.

In the event of a short circuit causing the fuse to blow, the lower screw is forcibly blown downward into the oil by the pressure, thereby breaking the arc very quickly. Any excess pressure is taken by the oil, which is able to percolate to the outer porcelain casing through the holes mentioned. All the pressure is therefore taken by the upper half of the metallic cylinder, and there is none on the porcelain itself.

To replace a fuse, the whole of the metallic portion can be removed from the porcelain, leaving the latter clear, and therefore easy to clean, while the screws and fuse wire can be easily replaced in a few minutes.—P. Charpentier, *Revue Générale de l'Electricité*, Jan. 1, 1921. Abstracted by *Technical Review*.

SOME TRANSMISSION LINE TESTS

IN view of the tendency in this country to adopt the 220,000-v. pressure as the standard for long distance transmission the corona loss tests which were recently made by W. W. Lewis should be of considerable interest. The tests were made on a transmission line 101.5 miles long, extending from Junction Dam to Grand Rapids and also on the additional 47.3 miles extending from Grand Rapids to Kalamazoo. The details of the transmission lines, methods of tests and of the results will be found in the *Journal of the American Institute of Electrical Engineers* for June, 1921, pp. 492-506. The following conclusions were arrived at:

Corona losses at approximately 210 kv. at the generating end and 225 kv. at the receiving end of a 100-mile line of 110,000 cir. mil. conductor have been recorded.

The losses in general follow Peck's law, with some deviation especially at the lower voltages, where the tested loss is as a rule less than the calculated.

A current in the grounded neutral was encountered which at the higher voltages was about 40 per cent of the line current. This current begins at about the normal line voltage. It is apparently due to the corona which causes a pulsation in the voltage wave and a triple-frequency current to flow through the capacitance to ground and back through the grounded neutral.

The line charging current, the current in grounded neutral and the rise in voltage along the line are all greater than calculated from the geometrical capacitance. This may be accounted for by an increased capacitance due to increased diameter of conductor caused by corona. Harmonics introduced into the voltage wave by the corona may contribute to the effect noticed.

The tests indicate a difference in corona loss with the neutral grounded and isolated, probably due to the flow of triple-frequency current in one case, and the distortion of voltage by triple-frequency component in the other.

The tests brought out the danger of overvoltage across legs and between neutral and ground with γ-γ connection. They

also clearly indicate the desirability of operating a transmission line below the corona voltage, thus avoiding corona loss and its accompanying effects.

DISCHARGE THROUGH AN ALUMINUM-CELL LIGHTNING ARRESTOR

THE aluminum cell is believed to be most nearly ideal for protection of extra high-tension transmission systems, but very little is known of the conditions of breakdown or discharge. The electrode surface is covered with an O_2 gas film partly converted into AlO_2; outside the gas layer there is a slimy film of $Al(OH)_3$. Thus a series of resistances and capacities are formed. Experiments were carried out to obtain the dynamic characteristic (curve of instantaneous voltage vs. amperage) of the discharge, especially at higher frequencies. The curve is nearly an ellipse at 250-1,000 cycles per second. Interpretation of the characteristics of these frequencies shows very desirable qualities for lightning arrestors: (1) The condenser action of the film makes the charging current increase with frequency; (2) the discharge has less tendency to current recurrent surges; (3) reforming the film takes an appreciable time so that the discharge current may continue without disruptively puncturing it.—*Tohoku Imp. University. Technology Reports*, Vol. 1, pp. 161-176, 1920. Through *Chemical Abstracts*.

HYDROELECTRIC DEVELOPMENT IN ITALY

THE high initial cost of hydroelectric development, the uncertain restrictions placed upon such development by states and government and similar factors have retarded the development of the smaller water powers in the United States. Where coal prices are high and other conditions more favorable the possibilities of replacing the energy derived from coal by that derived from the waterfall is being fully realized. Italy has been making rapid progress during the last few years. In 1915 her electric power resources were estimated at 2,500,000,000 kilowatt hours per annum. This figure had been increased to 3,700,000,000 before the end of the war and approaches 4,000,000,000. The capital invested in these hydroelectric power companies has reached now 1,500,000 lire. In the years from 1915 to 1920, 265,000 hp. was added and plants now under construction are expected to add 400,000 more. Hydroelectric power has a direct influence not only upon those industries requiring power merely for the turning of wheels but particularly upon those chemical industries where high temperatures under exact conditions are desired or where electric current itself must be employed.

MAGNETOS FOR IGNITION PURPOSES IN INTERNAL COMBUSTION ENGINES

AT the beginning of the war Great Britain was cut off of the magneto supply and was compelled to develop its own magneto industry. The paper by Mr. E. A. Watson on Magneto Design which was recently read before the Institution of Electrical Engineers proves that the British engineers have made much progress in this direction.

The author discusses at length the electrical as well as the mechanical problems involved. Electrically the magneto may be considered as a high tension alternator in which a special artifice is employed to obtain a rapid movement of the flux relative to the armature winding at one particular instant, while keeping the armature speed at a low figure. This is effected by using a portion of the revolution so that the currents induced in it tend to prevent any change in the flux leaving it and consequently produce distortion in the magnetic field. An interruption of the primary circuit cuts off this distorting current with the result that the magnetic flux rapidly returns to its original value, causing a high pressure in the secondary, which leads to spark passing between the points of the plug. These considerations necessitate that the value of BH should be as high as possible, and the curves connecting BH and H are therefore important factors in choosing the type of permanent magnet and the material employed in its manufacture. Great use is made in America of chromium steels which will give a (BH) max. of 240,000 to 250,000. Recently, however, the range has been extended by the introduction of the new cobalt steels as developed by Professor Honda and Sir Robert Hadfield. With 35 per cent of cobalt, values of (BH) max. as high as 900,000 can be reached, the value of Brem being from 10,000 to 10,500 with a value of HC of about 200 to 240. Such a steel is naturally expensive, but a much smaller amount is required. The higher coercive force opens up possibilities of simplification of design, owing to the permissible reduction in magnet length.

The author discusses at length the theoretical questions of the effect of armature reactance and resistance, the transformation of magnetic to electrical energy, the effect of the condenser and the choice of capacity. He summarizes the results of his reasoning as follows: 1. *Low-speed voltage.*—Dependent upon available magnetic energy, primary resistance, speed of rotation, number of secondary turns, energy losses and condenser capacity. Increases with increasing speed up to a limiting value, which increases with increase in available magnetic energy. 2. *Utility.*—At high speeds proportional to magnetic potential of distorted field and inversely proportional to number of secondary turns. At low speeds dependent upon speed and primary resistance. 3. *Energy in initial spark.*—At high speeds proportional to available magnetic energy. Dependent upon losses in iron of armature, etc., and partly on condenser capacity. If losses were absent the energy would be independent of voltage, but, owing to their presence, the energy decreases as the voltage is raised. At low speeds it is dependent upon speed and primary resistance. 4. *Total energy in spark and flame.*—This follows the same law as the energy in the initial spark, but is greater in value. Theoretically the total energy may be twice that in the initial spark. This energy is approximately that stored in a magnetic field of value 2B at a potential of H and is, therefore, $2BH/8\pi$ or $B\bar{H}/4\pi$. If, instead of allowing this field to collapse suddenly, we do work on it, maintaining the potential H until $B = O$, additional work $BH/(4\pi)$ will be done upon the field, and the total available energy will be $BH(2\pi)$. 5. *R.M.S. value of current in secondary circuit.*—Depends upon characteristics of magneto itself and also upon spark-gap resistance. A magneto may be made to give almost any reading desired upon an ammeter, by altering the constants of the circuit. In particular, adding capacity to the terminals will increase the reading several fold.

The following points form the basis of development in magneto design: (1) Improvement in material available, including the use of cheaper but equally effective substitutes; (2) better utilization of existing material; (3) improved mechanical design, tending to longer life and greater reliability in service; (4) simplification of parts, reducing cost of construction and elimination of difficult manufacturing problems.

In some cases these points are to a certain extent incompatible, notably (2) and (4), and a compromise has to be effected. The use of the new cobalt steel instead of tungsten steel has already been noted. Much might be done in the production of a satisfactory substitute for platinum for contact points. Tungsten is certainly not equal to platinum, having shorter life and much higher contact resistance.

Under heading (2) the author describes the use of laminated instead of solid pole-shoes. Much might be done in the direction of improved insulating materials and methods of insulation, so as to enable a better space factor to be obtained. There is room for improvement in the magnetic circuit. Examination of the armature reaction shows that certain portions of the ordinary horseshoe magnet are extremely ineffective. Under heading (3) great progress has been made, particularly as regards the contact breaker and its actuating cams. Under heading (4) much has been accomplished of late by the use of die castings, produced both in aluminum alloys and in alloys with a zinc base.—*Electrician* (London), Vol. 86, 476-477, 482-484, 487-489, April 22, 1921.

Progress in Mining and Metallurgy

Abstracts of Recent and Coming Papers

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

MAKING A 5 PER CENT NICKEL-CAST-IRON ALLOY IN AN ELECTRIC FURNACE

By D. N. Witman

One of the special uses to which the electric furnace has been put recently is the melting of an alloy of nickel and cast iron for the production of electrical-resistance grids. The metal sections of these grids are quite uniform for each pattern, but there is, among the various patterns, a variety of thicknesses. The cross sections vary from ½ by 3/16 inch to as small as ⅛ by ⅛ inch. The electrical resistance of a perfect casting lies within 10 per cent above or below the fixed listed resistance for each pattern. Good molding is essential to success in the making of these grids, for with absolutely correct metal, a variation of 0.01 inch in width and thickness of section on some of the patterns may mean as much as 12 or 14 per cent variation in resistance.

The service for which these castings are intended demands that the metal, even in the smallest castings, be very soft, showing an open, gray, highly graphitic structure in order that they may be resistant to shock and stand up well under rough usage. The metal used for this purpose is a gray iron alloyed with 4 to 5 per cent of nickel, which element, when the composition of the alloy is correct, imparts toughness and pliability to the metal and helps to overcome the tendency of metal to run white and become brittle because of the rapid cooling action of the sand mold. When cold, these castings can be twisted into various shapes, taking a permanent set without breaking. The alloy has approximately double the electrical resistance of ordinary cast iron.

On account of the nickel content of the metal, which raises the setting point of the alloy considerably above that for cast iron, causing the alloy to be sluggish at a temperature at which cast iron would have great fluidity, it is necessary to cast at a much higher temperature than would be required for cast iron. The temperature of the metal in the ladle, as determined by a Leeds & Northrup optical pyrometer, runs between 2,800 and 2,900 deg. fahr.

The required amounts of pig iron, scrap, and nickel ingot, together with some retort carbon, are charged into the furnace, the power turned on, and the melting done as quickly as possible. The melting down is carried on at the higher of the two possible voltages, viz., 110 volt, and the input of current fluctuates from 0 to 3,000 amperes per phase; the melting requires 1 hour to 1 hour and 10 minutes. If there is an accumulation of slag on the metal, because dirty metals were used in the charge or because some of the bottom has come up, it is skimmed off.

As there is not enough time to allow for chemical determinations, the necessary adjustments are made from observations of test pieces, so shaped as to indicate the character of the metal as cast in all sections from a feather edge up to ½ inch.

One of the peculiarities of this alloy of cast iron and nickel is a rejection of graphite from the metal when it is just melted, but when the metal is superheated it again takes up the carbon thrown out at a lower temperature. It is this property of nickel, throwing out graphite on cooling, that helps to make the grids soft and gray in the smaller sections and incidentally keeps the electrical resistance high.

The average power consumption, covering a 9-month period of operation, was 1,100 kw-hr. per ton, while the electrode consumption for the same period averaged 28 pounds per ton. These figures are rather high even for such a small furnace, but considering that the operation was, in a sense, experimental, and the installation more or less a makeshift, it is probably not as bad as the figures would seem to indicate.

The advantage of this method of melting may be stated briefly as follows:

There is no picking up of sulfur in the melting process, therefore all of the scrap alloy, such as gates, sprues, defective grids and over iron can be charged back into the furnace and nothing wasted. In fact, it is quite possible and just as easy to run a heat of 100 per cent scrap as it is to run one made up of pig iron, scrap and nickel.

The possibility of adjusting the metal to the proper composition while it is in the furnace.

The attaining of the high temperature necessary to cast the metal into very small section castings so that it will run clean and remain gray and tough.—Abstract of paper to be presented at the Wilkes-Barre Meeting, September, 1921.

ANTHRACOAL—A NEW DOMESTIC AND METALLURGICAL FUEL

By Donald Markle

Anthracoal is a mixture of small particles of anthracite coal and a matrix of practically pure carbon formed from the distillation of coal-tar pitch or other suitable bitumen. It is a hard, dense, homogeneous mass, with a silvery luster and, in color, varies from silvery to grayish black. When pushed from the oven it develops only partly the fingerlike structure of coke; but, unlike coke, it has a tendency to remain in blocky masses. When struck with a hammer or passed through crushing rolls, it breaks with an irregular fracture, similar to anthracite, but with very little fines. Due to its density, anthracite is harder, tougher, and stronger than coke.

Anthracoal can be made in a coke oven upon the same large scale as bituminous coke and can be produced with little greater expense; therefore it should prove a tremendous factor in utilizing the anthracite culm now going to waste.

The percentage of pitch used varies somewhat with the pitch, the character of the culm, and the method of mixing and grinding the material. In the tests at Syracuse, two grades of pitch were used, one with a melting point of 265 deg. fahr. and one 280 deg. fahr; both worked well. The amount of pitch used varied between 14.8 and 25 per cent, due to the method of proportioning. Ovens that contained 15 per cent pitch and 85 per cent culm, by weight, gave an excellent anthracoal and pushed readily. Ovens that contained 25 per cent pitch and 75 per cent culm also gave an excellent anthracoal but more of a thick carbon scale was noted in the ovens than when the mixture contained less pitch; also, the anthracoal was more porous than that made from the 15 and 17 per cent mixture. After many tests, both in the coke ovens and in the laboratory, it was found that between 16 and 17 per cent produced the best anthracoal with minimum fines and scale. Using below 16 per cent pitch, the anthracoal showed signs of attrition and not holding together, while above 17 per cent the surplus pitch flowed to the sides of the retort and produced a carbon scale that made a great deal of fines when pushed on to the dock.

A direct comparison between chestnut size of anthracoal and chestnut size of anthracite coal was made by an eight-day test of each in a kitchen range. The range performed the same service in each test, cooking three meals a day, heating water in the boiler, and, in fact, doing exactly the same work in each case. Observations were made as to amount of fuel fired each day, the amount of ashes produced, and the posi-

tion of the drafts during each run. The fire was started with wood at the beginning of each test and allowed to burn completely out at the end of the eight days. The fire was dampened at night and between meals with equal ease with the anthracoal and anthracite.

The total fuel consumed in each eight-day test was 288.5 pound anthracoal and 346.52 pound of anthracite, or 20.1 per cent more anthracite than anthracoal. As exactly the same service was obtained from each fuel, the results show that in this range the chestnut anthracite was 20 per cent less efficient than the anthracoal of the same size.

The evidence and data submitted thus far appear to point to a plant of regenerative non-recovery ovens; that is, a plant where the gas is brought directly from the charge into the flues and regenerative apparatus of the oven instead of passing through cooling coils and other apparatus for abstracting the by-products before it is burned.

The reasons for doing this are as follows:

1. If the gas is cooled first the sensible heat will be lost.

2. Removal of the by-products will lessen the heating value of the gas.

3. The by-products in the anthracoal gas are about one-third to one-half those in the bituminous gas, so that it is doubtful, with the uncertain and changing market, whether the recovery of the by-products would be worth the expense of the by-product apparatus which, in cost, represents one-half the cost of the ovens.

4. A non-recovery oven of the regenerative type will burn the gas direct, have the benefit of the sensible heat in the gas as it comes off the charge, and also have the additional heat value of the by-products which are not removed.

5. The ovens should prove to be self-sustaining and have ample gas for an exceptionally hot retort and quick coking in the non-recovery type.

6. A non-recovery type oven operating with anthracoal should produce 79 per cent more anthracoal in 24 hours than the same type of recovery oven. As the cost of manufacture in each case is almost the same with perhaps a little greater expense involved in the preparation of the anthracoal mix, the 79 per cent greater production of anthracoal than coke in 24 hours more than offsets the loss of the by-products.

7. A non-recovery type oven should prove more adaptable to the anthracite region. Its cost will be less to construct than the recovery type, and it will not require a skilled staff of chemists and workmen.

8. No market need be developed or additional sales force required, as in the by-product game, but rather the maximum amount of fuel can be produced, which can be handled in conjunction with the sale of anthracite coal.

Naturally, the success of the anthracoal will not be proved until a plant has been erected and the ovens operated on a commercial scale for a period of time. As a non-recovery regenerative oven has been rarely used in this country it will embody some changes in design from the regular regenerative type. However, this type of oven has been used with success in Germany and never presented any difficulties, as far as can be learned.—Abstract of paper to be presented at the Wilkes-Barre Meeting, September, 1921.

ANALYSIS OF SOME DRILL-STEEL TESTS

By FRANCIS B. FOLEY

THE responsibility for rock-drill failures does not rest entirely on the smith. Little has been published concerning the efficiency of drill steel, though the *Canadian Mining Journal* published the breakage record of a large number of hollow drill steels. This record indicates that most of the breaks occur during the early life of the steel and that as a given batch of steel is used, its percentage of breakage decreases. This fact, the article points out, is at variance with the much-talked-of theory concerning failure from crystallization and fatigue. It seems to point to the fact that the greater part of drill-steel failure from breakage is traceable to faulty manufacture, resulting in defects in the bore of the hollow steel from inclusions of slag or oxides, etc. As this defective material meets with early failure, it is weeded out. In addition, some breakage may be caused by a lack of proper condition with respect to heat treatment of the steel as furnished by the manufacturer.

In the article mentioned, the breakage of 1¼-inch hollow steel is given as 4.62 per cent for the early period of use, with a decrease to 3.35 per cent and 2.67 per cent with time in use. For 1-inch hexagonal hollow steel, the figures for breakage are 0.18 per cent, and 0.06 per cent; attention is called to the "enormous decrease in breakage by the use of smaller diameter drills." The figures are given as so many "drills sharpened," but there is no way of determining the percentage of tools broken, which must be considerably higher. For instance, from May 10 to August 9, or three months, there was a breakage of 2,883 drills out of 85,882 drills sharpened, which means an average of 32 broken steels per day out of 954 steels sharpened per day. Of course, some of these broken steels are made into shorter drills and are not lost, so that it is impossible to determine, from the figures, what the true percentage of drills broken was. The figures are from records of a total of over 190,000 tools sharpened.

BREAKAGE CAUSED BY FAULTY PRACTICE IN FORGING AND HARDENING

Breakage near the shank and bit ends of the steel is caused for the most part, by faulty practice in forging and hardening. Undoubtedly, the length of the steel, the kind of drill, and the difference in conditions existing in the testing of steel day by day have some bearing on the question of drill-steel failures. However, no steel has been consistently favored or penalized with respect to these variables.

LOCATION OF BREAKS IN DRILL STEELS

The total breakage is given in tables. A division is made of breaks that occurred within 10 inches of the bit end, within 10 inches of the shank end, between points 10 inches from either end but nearer the bit end, and between points 10 inches from either end but nearer the shank end. There was a total of 253 breaks, of which 173, or 68.4 per cent were in the half of the steel with the shank and 80 per cent in the half with the bit; 68 per cent of the breakage in the middle section of the steel was nearer the shank end than the bit end. That breakage is more prevalent in the half of the steel nearer the drill is to be expected when it is considered that, while the bit end is left free to yield, under the bending and vibratory stresses applied, the shank end is held fairly rigid in the drill. The tables show that about 90 per cent of the total breakage occurred within 10 inches of the ends of the steel; in other words, in the portion of the steel heated for forging. Some of this breakage may be said to be caused by fatigue, but the existence of such a phenomenon in steel is doubtful and is denied by many investigators.

In order to get a better idea of the location of breaks at the ends of the steel, a curve has been plotted. This curve has been derived by plotting at the even inch, breaks that occurred within ½ inch of that point. The position of maximum breakage in the tools is shown by the sketches of the shank and bit ends. The different steps taken in forging and hardening the steel are given in order that the full value of this curve may be appreciated. The shank end is considered first. When a collar is necessary, which was not the case in the tests under discussion, the fresh steel is heated for about 6 or 7 inches from the end and the collar is forged by upsetting. The condition of the metal at the farthest point of heating undergoes a rather sharp change from the annealed structure of the original material to a structure produced by the cooling from the forging temperature. The shank is then reheated for a distance, which probably varies up to 7 inches from the end, to a temperature above its critical range, but probably below the temperature for forging, and is plunged in oil. There is, then, a change from the annealed to the oil-quenched condition. When a lug or collar is forged there

may, therefore, be a number of structurally different zones, depending on the length of the steel heated for hardening; namely, the original structure of the bar, that produced in the cooling of a part of the bar heated for the upsetting operation but not worked, that produced in the upsetting, and, finally, the oil-hardened structure of the end. When it is realized that, while the shank end of the steel is supported in the chuck of the drill, the shaft of the steel outside the drill is subjected to considerable vibratory and bending stresses, the stresses that this heterogeneous region is expected to withstand will be appreciated. It is no wonder that most of the failures from breakage are found in this region.

Much the same kind of operation is undergone by the bit end of the steel. About 4 inches of it is heated for forging, and afterward only ½ to 1 inch is heated for quenching in water. Here, again, there are probably three zones of structurally different material.

To summarize, drill steel should be in the best condition when received from the manufacturer, free from imperfections of a mechanical nature and from impurities; it should also be in the best annealed condition to withstand the vibration and shock its service will entail.

There is, for a given steel, a temperature and a rate of cooling from this temperature that will produce the conditions that will best withstand the stresses of shock and bending.

Lack of uniformity in performance shows a lack of uniformity in the heat-treating operations, which may be overcome by the devising of means, of an automatic or "fool-proof" nature, that will attain the desired result without calling for excessive skill on the part of the smith.

Experimentation with the heat treatment of the shank and bit ends of the steel might lead to alterations in the present method of heat treatment that would do away with or mitigate the evil effects of the sharply defined zones of structurally different material, which must result to a more or less extent from present practice.—Abstract of Paper presented at the New York Meeting, February, 1921.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

THE CORROSION OF STEAM BOILERS

IN the early days of steam turbine development engineers hoped that the greater part of the boiler trouble would be over. The availability of the condensed steam with its freedom from all scale forming salts or traces of oil for boiler feeding purposes opened up prospects of a new era in the boiler room. Experience, however, showed that a very soft feedwater involved troubles of its own, though just why soft feedwater attacks boilers is not quite certain. The opinion most commonly held is that with very soft water corrosion is due to oxygen or carbon dioxide dissolved in the water. If this is so, it is desirable to avoid as much as possible the exposure of the condensate to the atmosphere and especially prevent all unnecessary agitation of the water in the presence of air. This led to the advocation of closed condensate systems. Another method consisted merely in bringing the feedwater into intimate contact with an extensive surface of unprotected iron, the idea being that the water should be allowed to satisfy its craving for iron by attacking metal specially provided for the purpose.

The engineer of a large London power station some time ago tried the experiment of filling his hot well with pieces of oil boiler tubes. They were strongly attacked by the water which was found to contain far less dissolved oxygen after passing over them than did the air pump discharge. In the course of time, however, the action practically ceased on account of the protective coating of rust which was formed on the tubes.

Mr. Kestner (paper before joint meeting of the Institution of Mechanical Engineers and Society of Chemical Industry, March 4, 1921) secured continuous operation by reversing the direction of flow of feedwater. In another instance interesting results were secured by fitting some of the boilers with cast iron economizers and the rest with steel ones. With the same feedwater corrosion took place in the boilers with cast iron economizers, but not in the others, the steel economizers themselves being attacked.

This would indicate that the corrosive capacity of feedwater is limited and may be eliminated by giving the water something to attack. In this connection it is stated that corrosion troubles were practically stopped in a certain steel economizer by filling it up with a mixture of lime and carbonate soda, removing the safety valves and subjecting the mixture to a protracted boiling at atmospheric pressure.

The attacks are often of an erratic nature. Sometimes one boiler out of a group is attacked; at other times the main feed line along the boiler fronts is safe while considerable trouble is experienced with the smaller vertical connections of the boiler drums. These facts point to the probability that something in the composition of the steel may be a determining factor. Tests by H. P. Gaze of the Central Electric Supply Co. would further indicate that ordinary commercial steel tubes supplied by the economizer makers suffer less from corrosion than charcoal iron tubes, which would dispose of the contention that modern steel is a poorer metal in respect to corrosion than old-fashioned iron.

The author arrives at the conclusion, however, that there is more than a possibility that pitting is not entirely due to chemical causes but is rather of an electrolytic nature. A lack of perfect homogeneity in the steel would tend to cause electrical currents to circulate between different points, the currents passing through the body of the metal and returning through the water. Wherever such currents left the metal they would carry iron into solution and so eat away the surface. The suspension of a zinc plate in the boiler might not suppress these parasitic currents, as it could do nothing to alter the fact of a relative difference of potential between two points on the boiler shell.

The general conclusion arrived at is that until we can get metal which is chemically homogeneous or can devise some effective method of protecting the surface or possibly rendering it passive, corrosion can only be prevented by paying careful attention to the impurities in the feedwater. In modern plants these consist of little more than dissolved gases, which fortunately can be eliminated or neutralized without very great difficulty when once the danger of their presence is properly appreciated.—Editorial, *Engineering*, Vol. 111, No. 2891, May 27, 1921, pp. 651-652.

COMPARATIVE TESTS OF STEELS AT HIGH TEMPERATURE

BY R. S. MACPHERRAN

DATA of tests made in the laboratory of the Allis-Chalmers Manufacturing Company to determine the comparative properties of various steels at high temperatures. The work was undertaken with the view to obtaining information as to the best material for use under operating conditions of 600 to 1,000 deg. fahr.

Measurements were made with an electrically-heated box in which the pyrometer head was practically in contact with the center of the test specimen. It was found that there is no one temperature at which all steels show a decided change in physical properties and this point varies with the composition and treatment of the steel.

The maximum tensile strength for rolled carbon steel annealed, and forged 3.25 per cent nickel steel annealed, occurs at about 600 and 650 deg. fahr.

The majority of the tensile strength curves, especially those of heat treated steels drop sharply as the temperature exceeds 800 deg. fahr. The effect of nickel in small amounts is slight, but in large percentages it tends to lower the temperature at which tensile strength begins to decline. Nickel steel is the only steel examined where the ductility materially diminishes at the higher temperatures, Monel metal bars behaving in the same manner.

Alloy steels containing chromium are less affected by rise in temperature than carbon steels and it has been generally found that apparently the introduction of metals forming carbides tend to strengthen steels at high temperatures.

This, to a certain extent, bears out the results of tests on the comparative retention of physical properties in alloy steels at 1,200 deg. fahr. or over by Leslie Aitchison, who finds the order of value to be tungsten, high chromium and 3 per cent nickel.—Paper read at the meeting of the American Society for Testing Materials, June 24, 1921. Abstracted through *Chemical and Metallurgical Engineering*, Vol. 54, No. 26, June 29, 1921, pp. 1153-1165.

CONCRETE REINFORCED WITH WOOD

SHORTAGE and at times complete lack of steel during the war has given an impetus toward the use of concrete and, concurrently, a method for reinforcing concrete by non-metallic materials. The Italian engineer, Mario Viscardini, in the early part of 1918 produced concrete beams reinforced by wooden lattice work. Tests on these beams have shown that in general they behave practically in the same manner as similar beams reinforced with steel, but, of course, the numerical values of elastic limit and total strength are different. If wood reinforced beams are overloaded they begin to crack, the cracks being larger and more clearly defined than in the case of steel reinforced beams, but like them they can be easily repaired providing the stress does not exceed the elastic limit.

The same results have been obtained in tests made by von Emperger and an Austrian commission who have carried out

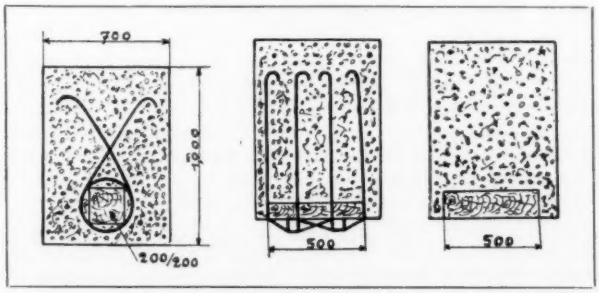


FIG. 1. DISTRIBUTION OF WOOD REINFORCING ELEMENTS IN CONCRETE BEAMS RECOMMENDED BY AUSTRIAN COMMISSION

an extensive series of tests on wood reinforced concrete beams and have found that the ratio of coefficients of elasticity of concrete and wood may be practically accepted to be unity.

One of the difficulties with wood reinforcement lay in the fact that in the first place the reinforcing elements had to be straight and in the second place it was not feasible to provide the usual abutments to increase the adherence between the concrete and reinforcing elements. Among other things it was found that tarring the wood reinforcing elements reduced the adherence, whereas a wash consisting of chalk cement, and in particular magnesia cement, over the wood reinforcing elements apparently increased the adherence. Further tests by the Austrian commission have also shown that the proportion of wood in reference to the total section of the beam should not exceed a certain percentage. In particular, beams of sections such as shown in Fig 1 proved to be best.

In Germany a beam has been developed employing both steel and wood reinforcing elements (Fig. 2). There the reinforcements which are in tension are of steel and the ones in

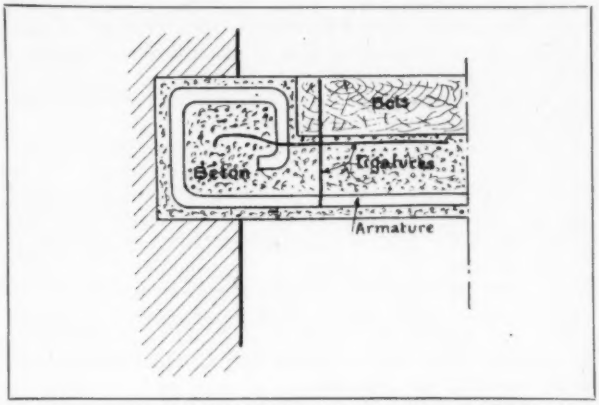


FIG. 2. GERMAN STEEL-WOOD REINFORCED CONCRETE BEAM (BETON, CONCRETE; BOIS, WOOD; ARMATURE, STEEL REINFORCEMENT; LIGATURES, TIE PIECES)

compression are of wood in addition to which the wood element happens to be placed so that it forms the top of the beam and may be used for attaching boards, etc. Theoretically such a construction is complicated but may have practical advantages.

One of the most interesting applications of wood reinforced concrete has been made in the construction of the steamer "Linnea" in Sweden. This is a 700-ton vessel built essentially with the framework of an ordinary wooden ship and concrete applied over it. The vessel has been in service on the Baltic and has apparently given satisfaction. (The original article describes an interesting method for launching it as concrete vessels can be conveniently launched with the usual gear.)—*L'Outillage*, Vol. 198, No. 10, March 10, 1921, pp. 238-284.

ALUMINUM CASTING

BY JOHN G. A. RHODIN

As regards the design of dies, the author discusses dies constructed as individual units with all clamping arrangements, etc., made and adapted for the die, and dies made in sections to suit a universal holder, like the plates in a filtering press. In England, the first method has been found to be best as it gives the designer more freedom in selecting the position of the casting of the die, combining vertical and horizontal sections, etc.

Some information is given as to the design of such dies and it is stated that the principal thing is to start working out the die from the main section and find out the smallest number of others feasible. So far such dies have been used only for making pistons of various more or less complicated design. Fans, propellers, etc., have also been made in quantity, but they belong to the class of machine parts that work without accurate fitting. Racing parts of machinery of great variety have also been cast in built-up dies and their number was increasing when the industrial stagnation came.

One of the advantages of these self-contained dies is that they can be put bodily in a furnace for heating and taken out ready for immediate pouring. With regard to limits of dimensions the writer has seen castings with rungs well over 2 feet and weighing more than 1 cwt. produced in dies of this type, such as gear cases and steering wheels for motor cars.

As regards the building up of a number of dies in the shape of plates which could be handled in a screw press, the author is less optimistic. For very simple things the plan is satisfactory, but in complicated castings it is claimed to be hopeless. The plates were supposed to slide on bars, but the bars proved to be in the way of everything when the casting had to be removed. The dowel pins holding the outside plate of the die were found to have a tendency to stick on slight provocation, and, in general, while the whole thing worked occasionally, universal application was abandoned.

Gravity method is not suitable for use on castings with very thin sections when high pressure must be used. Plunger pressure proved successful with small castings of antimonial lead but aluminum would spoil the fitting of a plunger in no time. Because of this, the majority of pressure casting machines are worked by compressed air.

The author tried a number of machines obtained from America in 1919 and says that with aluminum we had no luck. At the start really marvelous castings were produced, but in many cases the perfection was only apparent as they were full of gas bubbles under the skin.

His criticism of the design of these machines is that to begin with the permanent contact of the molten metal with iron is totally unnecessary and the same applies to the exposure of a large surface to the air. Furthermore, the gas in the castings is air which passes by hammer action through faulty design of the gooseneck.

As regards defects in aluminum castings, blowholes are mentioned. They are apparently the result of an evolution of gas dissolved in the metal and are nearly always associated with overheating of the metal. Certain impurities like manganese, and to a lesser extent, iron, enhance the effect.—Aluminum and Its Alloys in Engineering, serial article, Section 7, Chapter 5; *Engineer*, Vol. 138, No. 3416, June 17, 1921, pp. 635-636.

SOME DEVELOPMENTS IN CENTRIFUGAL FAN DESIGN

By F. W. Bailey and A. A. Criqui

THE authors claim that when multi-blade forward-curved blade fans supplanted the older type of straight radial blade fans, two very good characteristics of the old blade fans were lost. One of these was the pressure curve which rose continuously with the decrease in capacity and the other was the power curve which increased constantly with increasing capacity. In the forward-curved blade fan the pressure curve drops or flattens with decreasing capacity within the working range of the fan, while the power curve has a more abrupt rise as the load increases, a combination which sometimes causes serious trouble in fan installations. The flat portion of the pressure curve makes the fan very sensitive to resistance variation and if used at a capacity corresponding to this portion of the curve may make the fan run under or over the estimated capacity. This is particularly so if the friction of the system is slightly greater or less than was estimated or if an existing duct system is changed with the consequent change in resistance.

With the directly connected unit when a fan which has an abruptly rising power curve runs above the estimated capacity there is a decided danger of overloading the motor. With the motor-driven forward-curved blade fan run at this critical point in its range, it is necessary to supply an excess of motor power with a probability of running the motor at reduced capacity and therefore reduce the efficiency to guard against the possibility of the fan overloading. This represents a perpetual insurance payment when using a forward-curved blade fan under these conditions. The flat or drooping portion of the pressure curve also causes trouble in double-width fans or when two single fans blow into the same duct system, provided that the capacity comes within the range of this flat portion of the curve. If there is some difference in the resistance at the two inlets, which frequently happens, the capacity of one wheel will be reduced without any corresponding increase in pressure and this wheel then has no power within itself to regain the load, with the result that sometimes air will go in only one inlet of a double-width fan and the other wheel will merely churn the air in and out of its inlet.

A desirable combination of fan characteristics would be to retain the good features of the old radial blade fan and at the same time have the high capacity range insuring a small housing together with the higher efficiency of the forward-curved blade fan. During the past few years a new type of multi-blade fan has been developed which is said to combine these good features. This fan has blades which curve forward at the heel to meet the incoming air, but curve backward at the tip to discharge the air. Thus, while the blade of the forward-curved fan is a portion of the surface of one cylinder or one cone the blade of the new backward-curved blade is formed from the surfaces of two cylinders or two cones as shown in Fig. 3.

Fig. 4 shows the comparative pressure curves of a forward- and double-curved blade fan. The latter has the continuous rising pressure curve, which, when capacity decreases, builds up a pressure to overcome the added resistance. In double-width fans when one inlet is more restricted than the other, the tendency is for less air to flow through that inlet. In such a case the restricted wheel will build up a pressure to meet the added resistance and will thus retain its share of the load. As a result, a double-width fan of the double-curved blade

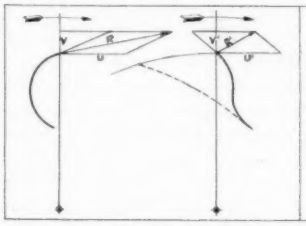


FIG. 3. COMPARISON OF THE FORWARD- AND BACKWARD-CURVED DESIGNS OF BLADES FOR CENTRIFUGAL FANS

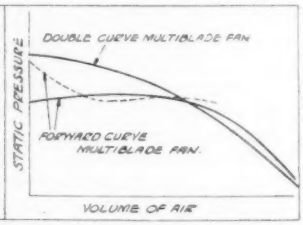


FIG. 4. COMPARISON OF PRESSURE-CURVES OF THE FORWARD- AND DOUBLE-CURVED BLADE TYPES OF FANS

type will divide the load between the two wheels throughout the whole range of capacities and neither of the parts will simply churn the air as in the forward-curved blade type.

The original article gives also curves showing the comparative static efficiencies of forward and double-curve blade fans and a comparison of their power curves.

The two types are not always competing. The forward-curved multi-blade fan is preferred where very high outlet velocity is required and noise is not objectionable. On the other hand, the double-curved multi-blade fan is essentially the medium capacity fan and lends itself particularly to that class of ventilating work where very high outlet velocities are not needed or desirable; at the same time it is decidedly a higher capacity fan than was the old radial blade fan.

Double-curved multi-blade fans are inherently higher speed fans than are those with forward-curved blades and this brings up the question of specifications. With the advent of the forward-curved blade trouble was experienced from noisy fans which was attributed to the higher speeds at which these fans ran. Engineers and architects, therefore, got the habit of writing into their specifications clauses which limited the speeds of multi-blade fans in order to insure large sizes or relatively slow-speed makes. As a matter of fact, the noise had very little to do with the speed of the fan. Double-curved blade fans do not cause as much noise and at the same time must be run at high speeds. Therefore specifications which fix low speeds would practically prohibit the use of double-curved blade fans.—*Journal of the American Society of Heating and Ventilating Engineers*, Vol. 27, No. 4, May, 1921, pp. 375-380.

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